PLANT AND ANIMAL RESPONSES TO A COMPLEX GRASS-LEGUME MIXTURE UNDER DIFFERENT GRAZING INTENSITIES

By

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To Mary,

for being a wife who provides love, patience and encouragement when they are most needed.

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'Florida' carpon desmodium [Desmodium heterocarpon (L.) DC.] is a long-lived perennial legume that persists under continuous grazing, but is often slow to establish. Aeschynomene (Aeschynomene americana L.) and phasey bean [Macroptilium lathyroides (L.) Urb.] are short-lived legumes (SLL) that exhibit rapid stand establishment and high forage quality. Three grazing intensities were imposed on a mixture of bahiagrass (Paspalum notatum Flugge), carpon desmodium, aeschynomene, and phasey bean to study seasonal and stocking rate effects on botanical composition, forage quantity and quality, soil seed reserves, and animal responses. The study was conducted in the summer of 1987, and the spring and summer of 1988.

Percentage carpon desmodium increased over the first season from 0.4 to 1.6%, and became stable during the

spring (7.9%) and summer (7.1%) of 1988. The contribution of SLL decreased over the first season from 4.1 to 1.6%, and was low in the spring (1.6%) and summer (1.5%) of the second year. Percentages of carpon desmodium and SLL in the sward canopy were not affected by stocking rate.

Herbage mass declined linearly with increases in stocking rate. In vitro digestible organic matter (IVDOM; r = 0.71) and crude protein (CP) concentration (r = 0.38) of total herbage in the summer of 1987 were correlated with percentage of SLL in the green herbage. Crude protein concentration of total herbage in the summer of 1988 was correlated (r = 0.68) with percentage carpon desmodium.

Soil seed reserves of aeschynomene increased linearly as stocking rate decreased. Seed production by carpon desmodium was poor the first year but was high the next year and was not affected by stocking rate.

Diet composition of SLL was high in both seasons and was not affected by stocking rate. Carpon desmodium decreased in the diet as stocking rate increased in the summer of 1987, but percentages in the diet in the summer of 1988 were not affected by stocking rate. Average daily gain (ADG) decreased linearly with stocking rate, but there was a curvilinear increase in gain per hectare with increases in stocking rate.

CHAPTER ONE
INTRODUCTION

Bahiagrass is a subtropical grass that is well adapted to flatwoods (spodosol) soils, but animal performance on bahiagrass is typically lower than on other subtropical perennial grasses (Chapman et al., 1972; Utley et al., 1974; Hodges et al., 1976). Furthermore, bahiagrass can be less productive than Cynodon and Digitaria species (Mislevy and Everett, 1981). Alternatives in managing bahiagrass pastures are needed to overcome deficiencies in quality and dry matter (DM) yields that limit animal production.

Nitrogen fertilization can increase the carrying capacity of bahiagrass pastures. Pitman (1983) obtained increases in carrying capacity of bahiagrass pastures from 364 to 536 animal days ha^{-1} following an application of 52 kg N ha^{-1}. Nitrogen fertilization is beneficial to animal production on perennial grass pastures, but the practice is becoming less feasible because production costs of N fertilizers are dependent on the supply of fossil fuels.

Minson (1980b) proposed that planting tropical legumes in mixture with perennial grasses is a practical means of providing both a high quality component and symbiotically-fixed N to pastures. Adding a legume component to

bahiagrass can increase output per animal and output per unit area of land (Pitman, 1983). Kretschmer et al. (1973) and Kalmbacher and Martin (1983) showed that the quality and quantity of available forage is increased when bahiagrass is grown in mixture with high-quality legumes.

Although many legumes have shown potential to improve forage quality and contribute N to perennial grass pastures, the commercial success of these species has been limited. Lack of persistence on flatwoods pastures is the major problem limiting acceptance of legumes by Florida producers. Clipping studies have shown that some legumes can persist over several years in mixtures with grasses (Kretschmer, 1970; Kretschmer et al., 1973), but results have been less promising under grazing (Pitman and Kretschmer, 1984; Pitman et al., 1988). Further evaluation of introductions and examination of grazing strategies to optimize legume persistence are necessary if the contribution of forage legumes to animal production in Florida pastures is to be achieved.

Low-growing, seed-producing perennials have demonstrated the most persistence under grazing (Pitman et al., 1988). Perennation and the production of seed to replenish plants lost due to defoliation are important attributes in maintaining legume stands through subsequent growing seasons. Annual legumes can persist if they are tolerant of grazing and capable of reseeding themselves, but seed yields are dependent on grazing management

(Gildersleeve, 1982; Sollenberger and Quesenberry, 1985) and environmental conditions (Pitman et al., 1988) through the grazing season.

A perennial legume that has shown potential in south Florida pastures is carpon desmodium [Desmodium heterocarpon (L.) DC.]. The cultivar, 'Florida', was released in 1979 and is the only cultivar that is commercially available in Florida (Kretschmer et al., 1982). The legume has persisted under continuous grazing, the grazing system most commonly used by Florida cattlemen. Carpon desmodium initiates growth in the early spring and can tolerate the low moisture conditions that are typical during the spring months in peninsular Florida. The legume is often difficult to establish, however, sometimes taking two to three growing seasons, which has limited its commercial acceptability.

Planting carpon desmodium in combination with short-lived, rapidly established legumes is an approach to obtaining legume contribution to the pasture during establishment of the persistent perennial. If this approach is to be used in commercial production, information is needed regarding the grazing intensities necessary to allow stands of the SLL to be maintained, yet restricting grass growth to a level that allows establishment of the perennial legume. Research was conducted to examine the effect of grazing intensity on the establishment of carpon desmodium when planted in

combination with two short-lived legumes in 'Pensacola' bahiagrass pastures. The short-lived legumes used in this study were aeschynomene and phasey bean. Aeschynomene is the most widely used forage legume in Florida (Hodges et al., 1982), but it is an annual and requires management for stands to persist and regenerate by natural reseeding (Gildersleeve, 1982; Sollenberger and Quesenberry, 1986). Phasey bean is a short-lived perennial that lacks persistence under grazing, and is currently being used in Australia as a pioneer legume in establishing perennial legumes (Whiteman, 1980).

The grazing study was conducted during the summer of 1987, and the spring and summer of 1988 to study the approach of using short-lived legumes as pioneer legumes in establishing carpon desmodium. The overall objectives of this research were (1) to determine seasonal and stocking rate effects on botanical composition of the mixture, (2) to examine the effects of grazing intensity on the quantity and nutritive value of available forage, (3) to examine stocking rate effects on soil seed reserves, and (4) to evaluate the effects of stocking rate and pasture responses on diet composition and animal performance.

CHAPTER TWO
LITERATURE REVIEW

Background Information on Bahiagrass, Carpon Desmodium, Aeschynomene, and Phasey Bean

Bahiagrass

General Description. Bahiagrass is a sod-forming, warm-season perennial that is native to Mexico and Central and South America (Gould, 1975). The grass is of the tribe *Paniceae* of the *Panicoideae* subfamily of *Poaceae*. It was introduced to the southeastern United States as a forage and erosion-control grass and is currently grown throughout Florida and in the Coastal Plain and the Gulf Coast regions (Gould, 1975). Bahiagrass is grown on approximately 1 million ha in Florida, which makes it the most common introduced pasture grass grown in Florida (Chambliss and Jones, 1981).

Bahiagrass was described by Sampaio and Beaty (1976) as producing short stolons that are partially embedded in the soil, but Watson and Burson (1985) referred to these structures as "often exposed rhizomes" which form a dense sod. Tillers are produced at terminal ends of stolons. Phytomers are added to tillers until a reproductive culm is produced or the tiller dies. An axillary bud of a phytomer near the terminal end of the stolon will then develop into

a new tiller (Sampaio and Beaty, 1976). Bahiagrass leaves are glabrous and linear, mostly 5 to 20 cm in length and 2 to 10 mm broad, and are flat, convolute or folded. Fertile stems are 25 to 75 cm in height and produce terminal racemes that are usually 5 to 10 cm in length and typically paired (Bogdan, 1977).

The growing points of bahiagrass are maintained near the soil surface, which allows the canopy to contain a high portion of leaf. Beaty et al. (1963) reported that leaf and reproductive culms in a stand of bahiagrass averaged 80 and 20%, respectively, over the growing season. The density of the canopy is highest just above the soil surface (Beaty et al. 1968), and can inhibit establishment and persistence of introduced legumes (Kalmbacher and Martin, 1983; Dzowela et al., 1986). The dense sod also allows bahiagrass to be competitive with common bermudagrass [Cynodon dactylon (L.) Pers.], a grass that commonly infests pastures in Florida (Mislevy and Hodges, 1976).

Common bahiagrass was introduced into the United States in 1913 (Scott, 1920); however, the grass is typically slow to establish and low in productivity (Chambliss and Jones, 1981). Several cultivars of bahiagrass have been released. Pensacola bahiagrass, which was first reported by Finlayson (1941), has become the most commonly-grown cultivar in Florida pastures (Chambliss and Jones, 1981). It is taller and more persistent, has longer and narrower leaves and tends to be more cold tolerant than

other released cultivars (Burton, 1946). 'Argentine' bahiagrass is more palatable than Pensacola, but is less cold tolerant and initiates growth later in the spring (Chambliss and Jones, 1981). 'Paraguay 22' is a cultivar used to some extent as a forage, and is similar to Argentine in cold tolerance and growth habit (Chambliss and Jones, 1981).

Adaptation. Bahiagrass is adapted to a wide range of environmental conditions. It grows best on sandy, light-textured soils, but growth can be sustained on heavy clay soils (Bogdan, 1977). Bahiagrass tolerates periods of low moisture (Henderson and Robinson, 1982) and flooding (Schroder, 1966). Similar to other tropical grasses, photosynthetic activity of bahiagrass is considerable under high-light intensity; however, bahiagrass can tolerate a higher degree of shading than most tropical grasses (Bogdan, 1977).

Stand Regeneration. The dense sod of bahiagrass will persist over subsequent growing seasons. Beaty et al. (1970) observed that maintaining intense clipping and low soil N levels over two growing seasons will thin bahiagrass stands, but reports of low persistence for the grass under poor management are lacking.

Forage Production. Growth rates for bahiagrass are typically lowest in the early spring and highest in late spring to mid-summer before declining in the late summer and fall months (Beaty et al., 1960). Dry matter

production of bahiagrass is variable and dependent on soil N status. Beaty et al. (1960) reported forage production of the grass responded to each increment increase in applied N. Production of DM for the lowest (0 N) and highest (269 kg N ha^{-1}) rates was 3,350 and 10,300 kg DM ha^{-1}, respectively, averaged over 3 yr. Other studies have observed similar responses for bahiagrass (Beaty et al., 1963; Blue, 1970; Kothmann and Hinnant, 1987). Thus, bahiagrass can be highly productive when soil N is maintained at levels that promote active growth.

Growing points at or just above the soil surface enable bahiagrass to have sufficient regrowth under intense clipping or grazing. Stanley et al. (1967) observed that clipping at ground level over four monthly clipping intervals resulted in plants being less vigorous, but capable of regrowth. Regrowth was increased with clipping heights above 2.5 cm.

Organic reserves in stolons are sufficient to prevent stress over short periods and are replenished as photosynthetic production exceeds plant energy needs (Sampaio et al., 1976). The ability of bahiagrass to tolerate close clipping also could be due to its canopy structure. Beaty et al. (1968) reported that 40% of the DM in bahiagrass sod is below a 2.5-cm height. Although percentages of live and dead tissues were not measured, results of the study suggested that maintenance of a low canopy height could

reduce portions of senescent material and provide higher percentages of photosynthetically-active tissue in bottom layers that contain the highest amount of DM.

Studies have shown that the DM production of bahiagrass is not affected by harvest frequency. Beaty et al. (1963) clipped Pensacola bahiagrass at intervals of 1, 2, 3, 4, 5, and 6 wk and reported little reduction in the seasonal production of bahiagrass as clipping frequency increased. In another study, Beaty et al. (1970) used the same frequencies over a 2-yr period to measure herbage production and sod density. Herbage production was not affected by clipping frequency, but after the second year, sods under 6-wk clipping intervals produced root and stolon yields that were 50 to 75% higher than those under 1-wk clipping intervals. It was concluded that over a short duration bahiagrass can be defoliated at a frequency that will provide maximum quantity of immature, relatively high-quality plant material, but over a long duration of intensive defoliation stands will eventually be thinned.

Nutritive Value. At similar maturities, bahiagrass is comparable to bermudagrass and digitgrass [*Digitaria decumbens* Stent.] in CP concentration and digestibility (Mislevy and Everett, 1981). During a grazing study, Sollenberger et al. (1988) observed bahiagrass to be consistently higher in CP and lower in digestibility than 'Floralta' limpograss [*Hemarthria altissima* (Poir.) Stapf et C.E. Hubb.].

The CP concentration of tropical grasses is of concern in livestock production because low levels at times during the growing season can depress intake (Minson, 1980b). Moore et al. (1969) reported CP concentration of Argentine bahiagrass, under continuous grazing, to decrease from 86 to 58 g kg^{-1} DM during the grazing season. Sollenberger et al. (1988) reported CP concentration in continuously-grazed Pensacola bahiagrass to be near or below 80 g kg^{-1} throughout the grazing season. Crude protein concentration of bahiagrass is often near the 60 to 80 g kg^{-1} DM range stated by Minson (1980b) to be a minimum before intake is limited. It appears that CP of the grass will respond to N fertilization. This was demonstrated by Prates et al. (1975) when CP concentration of Pensacola bahiagrass was maintained above 120 g kg^{-1} DM with split applications of a minimum of 40 kg N ha^{-1} at monthly intervals.

Bahiagrass is considerably higher in digestibility in an immature stage of growth than in a mature one. Moore et al. (1970) reported digestible organic matter (DOM) in sheep varied between 630 and 607 g kg^{-1} organic matter (OM) for 2-, 4-, and 6-wk growth and from 460 to 533 g kg^{-1} OM for 10-wk or more mature growth. Decreased digestibility with maturity is attributed to increased cell wall percentages (Moore et al., 1970; Prates et al., 1975). Pastures grazed to maintain bahiagrass in an immature growth stage have shown similar decreases in IVDOM as

the grazing season progressed (Prates et al., 1975; Sollenberger et al., 1988).

Animal Production. Average daily gain (ADG) and gain per hectare on 'Coastal,' 'Coastcross-1' (Chapman et al., 1972; Utley et al., 1974), and 'Callie' (Bertrand and Dunavin, 1985) bermudagrasses are higher than on Pensacola bahiagrass. Hodges et al. (1976) reported similar ADG for Pensacola and Argentine bahiagrasses, but responses for the bahiagrasses were inferior to those obtained on 'Pangola' digitgrass, 'McCaleb' stargrass (*Cynodon aethiopicus* Clayt. and Harlan), and 'Slenderstem' digitgrass (Digitaria pentzii Stent.). Sollenberger et al. (1988) found ADG on continuously grazed bahiagrass and Floralta limpograss did not differ, but higher levels of forage available for the latter suggested that animal output per hectare may be higher for limpograss if grazed to obtain better forage utilization (i.e., rotationally).

Average daily gain can exceed 1 kg in the spring and early summer, but losses in weight may occur in the late summer and fall months (Prates et al. 1975). The rapid maturity of bahiagrass increases the percentages of mature and dead material in the available forage and reduces pasture utilization (Hodges et al., 1976; Sampaio and Beaty, 1976). Low bite weight of grazing cattle may result from these conditions and cause reduced intake, which can decrease animal performance (Forbes et al., 1985).

The highest potential of bahiagrass is under adverse subtropical conditions that limit the productivity of higher quality grasses; however, animal production can be enhanced if grasses, other than bahiagrass, are introduced in areas that favor their production.

Carpon Desmodium

General Description. Carpon desmodium is a long-lived perennial that is native to Asia and the Pacific islands (Kretschmer et al., 1979). The legume is in the tribe Desmodieae of the Papilionoideae subfamily of Leguminoseae. Evaluation of ecotypes of carpon desmodium was initiated in 1964 at the ARC in Fort Pierce, Florida, and culminated in the release of the cultivar Florida (Kretschmer et al., 1982).

The growth habit of carpon desmodium varies from ascending to erect and can reach a height of 1 to 2 m at maturity. The legume is described as a subshrub or sometimes shrub, with woody stems (Kretschmer et al., 1976). Carpon desmodium has trifoliolate leaves, although unifoliolate leaves are common on seedlings (Kretschmer et al., 1979). Leaflets are smooth on the upper side and pubescent on the lower side and have a light green to yellow watermark (Kretschmer et al., 1979). Terminal leaflets are ovate to obovate in shape, with lengths of 4 to 6 cm, and are typically larger than lateral leaflets (Bogdan, 1977). Branches are diffuse with lengths of up to 1.2 m, and can

be prostrate under heavy grazing. Adventitious roots can sometimes form where stems touch the soil surface (Kretschmer et al., 1979). The legume produces pink or deep purple flowers on terminal and lateral racemes. Pods are oblong, and compressed with four to eight joints (Kretschmer et al., 1979).

In south Florida, carpon desmodium will initiate growth after the last frost and sustain a slow to moderate growth rate up until early summer. Growth in the summer is rapid until flowering begins in late summer. Kretschmer et al. (1979) estimated that growth in the spring, summer, and flowering periods contributed 30, 65, and 5% respectively, to the DM produced annually by the legume.

Carpon desmodium commences flowering in late August or early September. Seed maturation is concentrated and the seeds are ready for harvest from mid-November to mid-December (Kretschmer et al., 1976). Pods do not easily shatter which allows for high seed yields (Kretschmer et al., 1976). However, percentages of hard seed have been as high as 50% (Kretschmer et al., 1979).

<u>Adaptation</u>. A major attribute of carpon desmodium is its drought tolerance, however, the legume is intolerant of extended periods of flooding (Kretschmer et al., 1979). Dormant stands of the legume can tolerate freezing. Kretschmer et al. (1979) observed that a freeze did not severely reduce populations of the legume in the following growing season.

Stand Regeneration. Seedlings of carpon desmodium exhibit slow growth which causes establishment of the legume in grass sods to be slow (Kretschmer et al., 1979). Adequate accumulation of the legume, in mixture with grasses, often had not occurred until the second growing season (Pitman, 1983; Kretschmer and Snyder, 1982). Existing stands can regenerate in subsequent growing seasons, but the optimum grazing management for persistence and stand regeneration is not adequately understood.

Forage Production. Kretschmer et al. (1979) stated that carpon desmodium is persistent under heavy grazing. Pitman et al. (1988) rated and compared persistence among 50 tropical legume accessions, representing 33 species and 17 genera, sown in bermudagrass under light and heavy stocking rates. Carpon desmodium was one of four species that persisted under heavy grazing through the third year of grazing. Persistence did not differ between stocking rates for each year of grazing; however, stands of the legume declined over the 3 yr. In an earlier study, Pitman and Kretschmer (1984) observed that carpon desmodium in mixture with bahiagrass persisted over 2 yr of grazing, but the area covered by the legume was reduced.

Dry matter production of carpon desmodium was lower than that of 'Greenleaf' desmodium [*Desmodium intortum* (Mill.) Urb.], but higher than that of Siratro [*Macroptilium atropurpureum* (DC.) Urb.] at Ft. Pierce, Florida (Kretschmer et al., 1976). Kretschmer et al.

(1973) evaluated production of carpon desmodium in three separate mixtures containing either Pangola digitgrass, Pensacola bahiagrass, or 'Nandi' setaria (Setaria anceps Stapf). Annual production of the mixtures was 9.8, 9.1, and 8.1 Mg ha^{-1}, respectively. Monocultures of the digitgrass, bahiagrass, and setaria produced 2.6, 2.1, and 2.9 Mg ha^{-1}, respectively. Once carpon desmodium is established, the legume appears to be competitive with grasses and to contribute appreciable amounts of DM.

Nutritive Value. Carpon desmodium has a lower nutritive value than other legumes known to be of high quality. Kretschmer et al. (1982) reported IVDOM and CP of carpon desmodium to be lower than that of Siratro and three cultivars of stylo [Stylosanthes guianensis (Aubl.) SW.]. In an earlier study, Kretschmer et al. (1973) compared CP content and concentration between carpon desmodium and Siratro in mixtures with three different grasses. Mixtures containing carpon desmodium were lower in CP content, but the two grass-legume mixtures did not differ in CP concentration. Carpon desmodium mixtures averaged 904 kg CP ha^{-1} and were substantially higher than the 413 kg CP ha^{-1} averaged over grasses grown in monoculture and fertilized annually with 126 kg N ha^{-1}.

Apparent digestion coefficients in a digestion trial with steers averaged .348 for CP and .485 for OM (Kretschmer et al., 1976). These digestibilities are low

for a forage legume, but this may be due partially to pellets, that contained ground whole plants, being fed in the trial. Thus, the animals were forced to consume a certain quantity of stems, which are typically low in nutritive value and consumed in low amounts by grazing animals. Although CP digestibility was low, digestible protein content was observed to be high enough to meet requirements for growing steers.

Carpon desmodium contains tannins, which can negatively affect digestible protein and voluntary intake (Hammond, 1987). Kretschmer et al. (1979) reported that tannin concentrations were 20 to 30 g kg^{-1} DM for the legume and were low enough to not have a negative effect on animal performance.

Animal Performance. Evaluation of the potential of carpon desmodium to improve animal performance has been lacking. Digestion studies with the legume have indicated the quality of the legume may be low (Kretschmer et al., 1976), but conclusions should be with held until the quality of carpon desmodium is evaluated under pasture conditions that allow animals to selectively graze.

Aeschynomene

General Description. Aeschynomene, sometimes called jointvetch, is a warm-season annual legume. Some accessions are perennial, but ecotypes of Florida common aeschynomene behave as annuals (Kretschmer and Bullock, 1980;

Quesenberry and Ocumpaugh, 1981). The legume is of the tribe Aeschynomenae of the Papilionoideae subfamily of Leguminosae. Aeschynomene, which is native to the tropics and sub-tropics of the Western Hemisphere (Hodges and McCaleb, 1972), was originally collected in north-central Florida in 1930 (Hodges et al., 1982). A cultivar (cv. Glenn) was recently released in Australia (Bishop et al., 1985). Although no cultivars of aeschynomene have been released in Florida, it is considered the most widely adapted legume available for grazing in peninsular Florida (Hodges et al., 1982).

Aeschynomene leaves are pinnately compound, with the blade being divided into 25 to 60 leaflets. Leaves measure 2.0 to 7.5 cm and are sensitive to light and touch with the two rows of leaflets folding when disturbed (Hodges et al., 1982). The leaves and stems are glabrous (Bogdan, 1977). Flowers are yellow to violet in color and measure 6 to 10 mm in length. The flowers are located in axillary racemes and appear as clusters on segments that separate at maturity (Hodges et al., 1982). Segments are straight at the upper margin and constricted between segments in the lower margin (Bogdan, 1977).

Aeschynomene has an erect growth habit and can reach a height of 1 to 2 m when fully grown (Hodges et al., 1982). Growth is slow in the first 30 to 45 d, making it susceptible to grass competition and damage from grazing. Immature plants possess herbaceous stems that become woody as

the plant matures (Hodges et al., 1982). Basal buds on the crown are maintained at or just below the soil surface (Quesenberry and Ocumpaugh, 1981). Branching can be substantial under clipping or grazing by reducing the inactivation of basal buds from shading (Mislevy et al., 1981).

Aeschynomene has a short-day flowering mechanism (Kretschmer and Bullock, 1980). Flowering typically initiates from mid to late September in north central Florida (Quesenberry and Ocumpaugh, 1981; Sollenberger and Quesenberry, 1986). The legume is capable of producing large quantities of seed if grazing is deferred during flowering (Sollenberger and Quesenberry, 1986).

Adaptation. Aeschynomene is adapted to the sandy, moderately drained soils of peninsular Florida (Hodges et al., 1982). The legume is tolerant of long-term periods of flooding (Albrecht et al., 1981). Tolerance to waterlogged soils is a desirable attribute in Florida because 60% of the state is subjected to seasonal flooding (Allen, 1977). However, the legume is stressed under conditions of soil moisture deficits (Albrecht et al., 1981). In Florida, low amounts of rainfall in the middle to late spring often result in the loss of stands of aeschynomene seedlings (Hodges et al., 1982). Aeschynomene lacks cold tolerance, and growth will cease once temperatures drop to or below 10° C (Hodges et al., 1982).

Natural Reseeding. Aeschynomene is capable of producing enough seed under grazing for natural reseeding, but seed yields for the legume are dependent on grazing management (Gildersleeve, 1982; Sollenberger and Quesenberry, 1986; Sollenberger et al., 1987b). Grazing has been suggested to decrease inflorescence density and assimilate supply to inflorescences, and delay seed set to periods of time when climatic conditions are less favorable (Sollenberger and Quesenberry, 1986). Pitman and Kalmbacher (1983) obtained higher seed yields when grazing was ceased during vegetative growth. Seed yields were reduced from 280 to 180 kg ha^{-1} when grazing was continued through first flower, and decreased to 128 kg ha^{-1} when grazing did not cease until 27 d after first flower. Similarly, Sollenberger and Quesenberry (1986) found declines in seed yield per plant as animal removal was delayed. It was concluded that animal removal at first flowering offers a compromise between providing high-quality forage in the late grazing season and the need for high seed yields.

Gildersleeve (1982) observed higher seed yields per hectare by initiating grazing when aeschynomene reached 28 versus 45 or 54 cm in height. Sollenberger and Quesenberry (1986) found no relationship between initial height of defoliation and seed yield per plant. Higher seed yield per hectare with a low initial height of

defoliation may be related to increased persistence and vigorous regrowth when defoliation is initiated when the legume is at 20- to 40-cm heights (Mislevy et al., 1981; Sollenberger et al., 1987b). Soil seed reserves can facilitate reestablishment of aeschynomene when early growth of resident grasses is controlled to provide a suitable environment for germination and subsequent seedling growth (Tang and Ruelke, 1977).

Forage Production. Dry matter production by aeschynomene is primarily dependent on plant height when grazing is initiated and the level of grazing intensity. Mislevy et al. (1981) compared aeschynomene DM production at different combinations of heights for initial clipping, stubble, and regrowth. Highest production was achieved when initial height was 30 cm, followed by 90 cm regrowth. Branching was reduced for initial clipping heights of 60 and 90 cm, which indicated higher shading under these heights increased the number of dead or inactive bud sites. Production was highest for 8-cm stubble heights, while plants cut to an 18-cm stubble exhibited faster regrowth. The higher clipping height evidently removed fewer axillary buds.

Grazing studies have demonstrated that DM accumulation of aeschynomene is affected by legume height when grazing is ceased during establishment, and when grazing is initiated once the legume has established (Gildersleeve, 1982; Sollenberger et al., 1987b). Sollenberger et al. (1987a)

reported grazing should be ceased on Floralta limpograss-aeschynomene pastures once the legume has attained a height of approximately 5 cm during the establishment phase. At this height, the legume is competitive with the grass and, thus, contributes a higher percentage of DM to the association. Legume productivity was further shown to be maximized when grazing was initiated when aeschynomene was 0.2 to 0.4 m tall.

Nutritive Value. Until recently, Aeschynomene species were thought to be of little agronomic value (Bogdan, 1977). Recent research has shown that, in associations with tropical grasses, aeschynomene can provide CP concentrations and DOM above quantities offered by grasses (Kalmbacher and Martin, 1983; Sollenberger et al., 1987c). However, highest concentrations of CP and DOM are found in the upper, more leafy part of the plant (Hodges and McCaleb, 1972, Mislevy and Martin, 1985).

Gildersleeve (1982) analyzed CP and IVDOM in leaf and stem fractions of 10 Aeschynomene accessions. Leaf fractions were considerably higher in quality than were stems. Leaf fractions had CP concentrations of 169 to 264 g kg^{-1} DM, and IVDOM ranged from 630 to 769 g kg^{-1} OM. Stem fractions, which become woody as the plant matures, had CP concentrations of 54 to 71 g kg^{-1} DM and IVDOM ranged from 301 to 401 g kg^{-1} OM.

Sollenberger et al. (1987c) reported minimal changes in the leaf quality of aeschynomene with plant maturity.

Crude protein remained above 230 g kg^{-1} DM throughout the growing season. Digestible OM was approximately 700 g kg^{-1} OM during the season, but declined to 650 g kg^{-1} OM during late October and early November. Crude protein and DOM concentrations in stem fractions declined dramatically as the legume matured.

Mislevy and Martin (1985) demonstrated that IVDOM for the whole plant decreased 32 g kg^{-1} OM for each increase of 15 cm in plant height. Leaf to stem ratios decrease as aeschynomene matures (Sollenberger et al., 1987b), and the higher portion of low quality stem adversely affects whole plant digestibility.

Animal Performance. Pitman (1983) reported ADG of 0.58 kg on bahiagrass-aeschynomene associations compared to 0.48 kg on bahiagrass fertilized with 224 kg N ha^{-1}. Average daily gain also was higher on a aeschynomene-limpograss mixture than on N-fertilized Floralta limpograss (Rusland et al., 1988).

Weaned calf percentage, a measurement of reproductive performance, tended to be higher for cows on perennial grass-aeschynomene mixtures than on perennial grass monocultures (Hodges et al., 1974). However, studies of reproductive performance on grass-summer legume mixtures are lacking and are needed to provide conclusive results on the potential of legumes to improve cow-calf production on Florida spodosols.

Phasey Bean

General Description. Phasey bean is a short-lived perennial legume that will behave as an annual in less favorable environments (Pitman et al., 1986). The legume is in the tribe *Phaseoleae* of the *Papilionoideae* subfamily of *Leguminoseae*. Phasey bean was originally placed in the genus *Phaseolus* but was later reclassified as a *Macroptilium* species. Phasey bean is native of tropical South America, but is widely naturalized in Southeast Asia, Australia, southern North America, and parts of Africa (Cameron, 1985). The only released cultivar is 'Murray', which was selected in Australia for increased vigor and leaflet size (Cameron, 1985).

The growth habit of phasey bean varies between erect and viney. Mature plants may reach a height of 90 to 150 cm, and develop a twining growth habit when growth exceeds 90 cm (Pitman et al., 1986). Lower stems become woody as the plant matures. Leaves are trifoliolate with ovate to lanceolate leaflets that are typically 2.5 to 7.5 cm in length (Bogdan, 1977). Flowers are red to purple in color and developed on semi-erect, axillary racemes (Cameron, 1985). Flowers are typically attached on alternate sides of the raceme. The racemes are approximately 15 cm long on peduncles up to 25 cm long (Cameron, 1985). Pods are 7.5 to 10 cm long, cylindrical, and contain up to 20 seeds. The pods become dehiscent and shatter upon maturity.

Phasey bean is self-pollinated (Cameron, 1985) and is a good seed producer (Pitman et al., 1986). Flowering is initiated 5 to 7 wk after planting (Brolmann and Kretschmer, 1973). Flowering occurs sequentially as the raceme develops over an extended period of time. Thus, individual racemes can have a full range of seed development from flowers to shattered pods. Plants also flower indeterminately which further increases the time period of seed production and natural dispersal (Pitman et al., 1986). An extended flowering period and the shattering of pods cause harvested seed yields to be low, which limits the commercial availability of seed.

Adaptation. Phasey bean is adapted to a wide range of environments in the tropics and subtropics. The legume will grow in moderately dry to humid environments with annual rainfall amounts of 600 to 2000 mm (Bogdan, 1977). Phasey bean can tolerate seasonal drought (Thompson, 1988) and is quite tolerant of periodic flooding (Whiteman et al., 1984). Whiteman et al. (1984) observed that phasey bean growing in waterlogged soil for 21 d responded by producing more DM than plants grown in soil at field capacity. Although the legume is most productive in fertile soils, the plant is tolerant of infertile, acid soils (Pitman et al., 1986).

Stand Regeneration. Optimum management of phasey bean for maximum reestablishment in subsequent growing seasons has not been fully elucidated. However, grazing should be

deferred at a time that would facilitate higher seed yields and allow for the replenishment of organic reserves in the roots of defoliated plants.

Forage Production. Phasey bean initiates growth in the early spring and can produce appreciable amounts of DM. However, grazing and grass competition will cause stands of the legume to decline over time (Brolmann and Kretschmer, 1973; Pitman, 1983; Pitman and Kretschmer, 1984). Brolmann and Kretschmer (1973) observed Pangola digitgrass-phasey bean plots to gradually decline in percentage of legume over a 2-yr period and dramatically decrease in legume percentage after the second year. In a grazing study, Pitman (1983) reported phasey bean, in mixture with bahiagrass and carpon desmodium, reduced in percentage of available DM from 28.8 to 11.8% over one grazing season. Thus, stands of phasey bean appear to persist for only one to two growing seasons, although scattered plants may be evident in bahiagrass pastures for several years.

Othman and Asher (1987) studied the regrowth of defoliated phasey bean plants in a greenhouse experiment. A high cutting height that retained some flowers and pods was lower in regrowth than a short cutting height that retained no flowers or pods. Using ^{14}C labelling techniques, assimilate was partitioned in plants clipped at a height that retained pods. Assimilate supply to nodules and nitrogenase activity decreased during pod-fill, but

both rapidly increased at pod maturity. Regrowth was increased 170% when cut plants with retained pods were supplemented with ammonium nitrate. Developing pods appear to suppress regrowth of phasey bean by competing with new shoots for symbiotic nitrogen, and by competing with nodules for assimilate. This could be of consequence in pastures since plants are often only partially grazed and some pods often remain intact. An improvement of persistence with heavier grazing pressures would be doubtful; however, since phasey bean stubble with little or no residual leaf will exhibit slow regrowth (Brolmann and Kretschmer, 1973; Adjei and Fianu, 1985).

Depletion of phasey bean stands after 1 to 2 yr of grazing suggests that the legume has little potential for use in Florida pastures. Brolmann and Kretschmer (1973) and Pitman (1983) proposed that phasey bean could be planted as a pioneer legume, as is currently practiced in Australia (Whiteman, 1980), in mixture with the slowly establishing perennial legumes.

Nutritive Value. Phasey bean is similar to aeschynomene in chemical composition (Adjei and Fianu, 1985). Milford (1967) compared chemical composition and digestibility of numerous perennial legumes fed to sheep. Over the growing season, the CP and IVDOM of phasey bean ranged from 122 to 192 g kg^{-1} DM and 434 to 647 g kg^{-1} OM, respectively. These observations were similar to those

determined for Siratro, but the ranges were lower than those observed for alfalfa (Medicago sativa L.).

Leaves and stems of the legume can both contain relatively high percentages of CP. Muldoon (1985) measured N concentration in leaves and stems of phasey bean at 10- and 13-wk maturity. Nitrogen decreased in leaves from 41 to 32 g kg^{-1} DM, and the concentration in stems decreased from 22 to 14 g kg^{-1} DM. Leaves contained more N than did stems, but both contained high amounts of N when measured at the two maturities. Upper stems of phasey bean remain herbaceous through the grazing season, which is an attribute in terms of nutritive value. Over a 4-yr study, plots of Pangola digitgrass-phasey bean averaged 2422 kg CP ha^{-1} whereas plots of the grass in monoculture contained an average of 1143 kg CP ha^{-1} (Brolmann and Kretschmer, 1973).

Animal Performance. Grazing evaluation of phasey bean has been limited, but the few studies that have examined this legume have shown it to be high in quality (Pitman, 1983; Pitman et al., 1986). Pastures containing predominantly phasey bean have produced ADG of 0.9 kg during the summer months (Pitman et al., 1986). Pitman (1983) reported ADG of 0.51 kg for a bahiagrass-phasey bean mixture which did not statistically differ from gains achieved on a bahiagrass-aeschynomene pasture. Gains on the bahiagrass-phasey bean mixture did not differ from those obtained on N-fertilized bahiagrass, but the gains

tended to be higher for the grass-legume mixture.

If adequate quantities of phasey bean can be maintained through the growing season, the legume appears to have potential to provide high quality forage during the middle to late summer months when the quality of tropical pastures is typically low. Studies of the effect of availability of phasey bean on cattle weight gains have been lacking and are necessary if the potential of the legume is to be thoroughly evaluated.

Forage Quality

Concepts and Techniques

The quality of a forage is determined by its nutritive value and voluntary intake (Mott and Moore, 1970). Nutritive value refers to the chemical composition of the forage, its digestibility, and the efficiency with which the digested products are utilized by the animals. Voluntary intake of forage is dependent upon acceptability of the forage, accessibility of preferentially grazed plant parts, and the rate at which the forage passes through the digestive tract (Mott, 1959; Mott and Moore, 1970). Forage quality is highly variable because of differences between plant genotypes, seasons of the year, and stages of maturity (Moore, 1980).

Forage quality is best described in terms of animal performance. Although animal performance is affected by

forage quality, performance also can be influenced by forage quantity, the animal's genetic potential, and the availability of supplemental feeds (Moore, 1980). Mott (1959) described conditions that allow forage quality to be the sole factor in determining animal performance. These conditions are that (1) animals have a potential to produce and are uniform among groups being used to compare forages, (2) forage is available in quantities that exceed *ad libitum* intake, and (3) there are no sources of supplemental energy or protein.

Another useful definition of forage quality is voluntary intake of digestible energy, assuming the forage is balanced with respect to protein, minerals, and vitamins (Mott and Moore, 1970; Moore, 1981). Intake of DOM also is acceptable since it is closely related to digestible energy intake (Minson, 1980a).

Voluntary intake and nutrient digestibility function independently in affecting forage quality. In a study of 41 forages, Moore et al. (1980) reported a correlation of 0.69 between intake and digestibility. Intake was reported by Heaney (1970) to be more variable than digestibility over the range of low- to high-quality forages. Therefore, a given quality of forage can be achieved with different ranges of intakes and digestibilities (Moore, 1981).

Laboratory analyses are routinely performed on samples of forage to estimate quality. Digestibility can be estimated using an in vitro technique (Moore and Mott,

1974). Nitrogen analysis also is useful because CP concentration below a range of 60 to 80 g kg^{-1} DM limits intake (Minson, 1980b).

Forage Quality of Grass-Legume Mixtures

The digestibility and voluntary intake of tropical grasses are typically less than those of temperate grasses (Minson, 1980b). Differences in digestibility between tropical and temperate grasses have been associated with anatomical differences (Akin and Burdick, 1975). Lower intake of tropical grasses is sometimes related to deficiencies in protein. Minson (1980b) analyzed protein of six tropical grasses (28 samples) and reported 24% of the observations were below 60 g kg^{-1} DM. It was suggested that protein deficiencies in tropical pastures could be overcome by planting high protein legumes in mixture with tropical grasses.

Minson and Milford (1967) fed different proportions of legume and mature Pangola digitgrass to sheep. Voluntary intake of the legume was approximately double that of the grass. Feeding 100 to 200 g of the legume daily resulted in increased consumption of the grass. Intake of legume was concluded to have a positive associative effect on the consumed grass by eliminating a protein deficiency.

Animal performance has been improved when tropical legumes were offered in combination with grasses under Florida conditions (Hodges et al., 1974; Pitman, 1983;

Rusland et al., 1988). Furthermore, studies with aeschynomene have shown the legume to provide a high-quality component to tropical pastures during periods when the quality of tropical grasses is typically low (Sollenberger et al., 1987c; Rusland et al., 1988).

Forage Quantity

Animal Response to Forage Quantity

Yield of animal product per area is determined by animal potential and the quality and quantity of available forage (Mott, 1980). If animal potential is assumed to be constant, then individual animal performance on pastures grazed under an optimum grazing pressure is dependent on forage quality, and the number of animals a pasture will carry at the optimum pressure is a function of forage quantity (Mott, 1960; Mott, 1980). The optimum grazing pressure was described by Mott (1960) as the pressure that establishes an equilibrium between plant growth and animal nutrient requirements. Although weight gains under optimum grazing pressures are directly related to forage quality, changes in animal response as grazing pressures deviate from the optimum will be related to the corresponding changes in forage availability (Mott, 1960).

Mathematical models have been proposed, ranging from simple linear to complex curvilinear regressions, which explain the relationship between stocking rate and ADG.

From results of other grazing studies, Cowlishaw (1962) and Jones and Sandland (1974) both concluded that linear models best described the relationship. Conversely, other studies have indicated that the relationship is curvilinear (Harlan, 1958; Mott, 1960; Conniffe et al., 1970; McCartor and Rouquette, 1977). Petersen et al. (1965) theorized that ADG is constant as stocking rate is increased to a "critical" stocking rate. Beyond this stocking rate, ADG is inversely related to stocking rate. Detection of linearity is likely due to a narrow range of stocking rates. However, Riewe (1961) stated that a linear regression model can adequately describe the relationship up to a point of maximum ADG.

The complexity of grazing systems is attributed to climate, growth patterns of the forage components, composition and digestibility of the sward, and characteristics of the canopy. Connolly (1976) attributed these factors to the inconsistency among grazing studies in their assessment of the relationship between stocking rate and ADG. Thus, extrinsic and intrinsic factors involved in vegetative growth cause stocking rate, as a sole variable, to be of questionable value in studying animal performance in pastures. A more direct and useful approach is to relate animal performance to forage availability.

The relationship between forage availability and ADG has consistently been shown to be curvilinear (Duble et al., 1971; Adjei et al., 1980; McCartor and Rouquette,

1977; Guerrero et al., 1984). Daily weight gains increase as available forage increases up to a certain quantity where maximum weight gains are attained and do not respond to further increases in herbage. Duble et al. (1971) measured ADG of steers as herbage mass (kg DM ha^{-1}) increased for tropical grasses that differed in digestibility. The maximum ADG that was attained was directly related to the digestibility of the available forage. The maximum ADG also was achieved at a lower herbage mass as digestibility increased. These results indicate that forage quality is the limiting factor for animal performance when availability is above a certain quantity, but availabilities below this quantity will cause quality and quantity to interact as factors that affect animal performance.

Reductions in animal performance under low availabilities of forage are evidently the result of depressed intake. Jamieson and Hodgson (1979a) reported that intake in calves grazing perennial ryegrass (*Lolium perenne* L.) declined 18% as herbage allowance decreased from 90 to 20 g DM kg^{-1} body weight (BW). In another study, Jamieson and Hodgson (1979b) observed intake reductions of 24 and 39% for calves and lambs, respectively, as the herbage mass of perennial ryegrass was progressively reduced from 3000 to 1000 kg OM ha^{-1}. It was concluded that limited intake in both experiments was due to reduced bite weights that were

not sufficiently compensated for with increases in bite rate and grazing time. Intake of a forage will be maximum at a certain quantity of available forage when quantity and accessibility of selectively grazed plant parts are optimal.

Jones (1981) proposed a hypothetical relationship between ADG and stocking rate which suggested that animal performance is depressed on under-utilized pastures. Stobbs (1970) reported that weight gains of steers on a *Hyparrhenia rufa* (Nees) Stapf and stylo mixture were lower for a stocking rate of 2 animals ha^{-1} than for heavier stocking rates of 3 or 5 animals ha^{-1}. In another study, Stobbs (1973a) observed limited intake on stands of *Chloris gayana* Kunth. and *Setaria anceps* Stapf ex Massey that were grazed at 6- to 8-wk maturities. Intake was reported to be limited by low bite weights that resulted from poor prehension of the relatively inaccessible leaf fraction.

Animal Response to Grass-Legume Mixtures

Over a range of grazing pressures, animal performance on mixtures of forage species is affected by availability of forage and changes in botanical composition that can occur under different grazing intensities. In a review, Roberts (1980) concluded that the relationship between ADG and stocking rate varies greatly among different grass-legume mixtures. Average daily gain will show a negative linear decrease if the species are similar in competi-

tiveness and animal acceptability. However, departures from linearity will occur if the mixed species differ in these attributes. Under low grazing pressures, the taller species will suppress growth of the low-growing species. In mixed pastures under high grazing pressures, the species that is least able to recover from defoliation will eventually be eliminated. Average daily gain will be depressed if the dominant species is of lower nutritive value or palatability than the suppressed species (Roberts, 1980). Thus, mixtures should be grazed at intensities that optimize the growth of the least competitive species. A palatable legume typically will be at a competitive disadvantage to the grass that normally has a higher growth rate and lower nutritive value, especially in the case of tropical grasses that utilize the C-4 photosynthetic pathway, as compared to C-3 legumes.

Stobbs (1970) subjected two grass-legume associations to three stocking rates. One mixture contained _Hyparrhenia rufa_ and stylo and the other contained guineagrass (_Panicum maximum_ Jacq.) and siratro as respective grass and legume components. Weight gains decreased with increases in stocking rate for the _Panicum_-siratro association. However, weight gains were lowest on the low stocking rate for _Hyparrhenia_-stylo mixture. Proportion of legume was low for this grazing intensity which resulted in an accumulation of mature grass that was low in leaf percentage. The results of this study indicate that some

grass-legume associations must be moderately to heavily grazed for the legume to contribute to animal performance, while in other mixtures, the legume can persist and contribute at a wide range of grazing intensities.

Elimination of the legume from mixtures under heavy grazing can result in the encroachment of undesirable weedy species which can further reduce animal performance. Partridge (1979) reported that a heavy grazing intensity on a (*Dichanthium caricosum* L.)-siratro mixture resulted in loss of the legume and subsequent replacement with native legumes. Infestation of the native legumes caused a dramatic decline in animal performance. Similar responses have been reported for heavily grazed mixtures of *Panicum maximum*-stylo-centro (*Centrosema pubescens* Benth.; Eng et al., 1978).

Legume Persistence

The use of legumes in tropical pastures is limited by their lack of persistence under grazing. Botanical composition is affected by the interrelation of defoliation and environmental stresses, and competition (Grime, 1974). Evaluations conducted in Florida have shown that most species of legumes are intolerant of the stresses of grazing and grass competition (Pitman and Kretschmer, 1984; Pitman et al., 1986; Pitman et al., 1988).

Grime (1973) attributed the ability of a species to be competitive to (1) a tall stature, (2) a growth habit that

allows extensive exploitation of the above and below ground environment, (3) a high maximum relative growth rate, and (4) a tendency to deposit a dense layer of litter on the soil surface. These characteristics can be used in evaluating forage legumes, or else, grazing can be managed in a manner that restricts grass growth and allows legumes to be more competitive. Evaluations conducted by Pitman et al. (1988) indicated that Vigna parkeri Bak., carpon desmodium, and Desmodium barbatum Benth. are low-growing, seed-producing perennial legumes that are adapted to continuously-grazed bahiagrass pastures if grazing pressures are high enough to restrict bahiagrass growth. Upright or viney legumes showed poor recovery under continuous grazing. However, Siratro and Vigna adenantha (G.F. Meyer) Marechal, Mascherpa, and Stainer are viney, perennial legumes that persisted if rotational grazing or light grazing pressures were used to provide adequate recovery of defoliated legumes.

Diet Selection

Concepts of Selective Grazing

Grazing animals exhibit a preference for leaf, particularly when there are large differences in quality between leaf and stem fractions (Stobbs, 1973b; Laredo and Minson, 1973; Chacon and Stobbs, 1976). The degree that leaves are selected is apparently influenced by decreased

quality and quantity of leaf fractions from the top to the bottom of canopies in tropical and subtropical pastures (Wilkinson et al., 1970; Stobbs, 1973b). Chacon and Stobbs (1976) reported that cattle selected 80% leaf in the early stages of defoliation of Setaria anceps pastures. High concentrations of stem in available forage during late stages of defoliation caused the leaf portion of diets to decrease to 23%.

Under limited availability of leaf, animals graze less selectively, but they appear to maintain a search for the relatively higher quality leaves. Chacon and Stobbs (1976) reported that intake was highly correlated to leaf percentage and leaf to stem ratios in the sward. Low bite weights have been associated with reduced intake under low availability of leaf (Stobbs, 1973a; Stobbs, 1973b). Increases in grazing time and bite rate can compensate for low bite weights (Ludlow et al., 1982). However, Stobbs (1973a) observed that intake by cattle was limited when grazing time and bite rate reached a maximum and bite weight was below 0.3 g OM. Results of these studies indicate that, under low availabilities, animals will search and manipulate swards in an attempt to select leaves for consumption.

Legume Selectivity

Although animals do not necessarily demonstrate nutritional wisdom in their grazing (Martin, 1978), it is

presumed that animals generally consume forage that is higher in protein and digestibility than that of the total available forage (Arnold, 1980). This would indicate that palatable legumes are readily selected for consumption. Milne et al. (1982) concluded that legume proportion in the diet of animals grazing grass-legume associations is affected by (1) proportion of legume in the sward, (2) relative distribution of plant parts of the grass and legume in the sward canopy, and (3) herbage mass, height and density of the pastures.

Diet composition on a temperate pasture was examined by Laidlaw et al. (1983) for sheep on a red clover (Trifolium pratense L.) and ryegrass mixture. A low herbage bulk density allowed the sheep to select for the legume throughout the sward canopy. Legume selectivity has been shown to be inversely related to bulk density for tropical pastures. Sollenberger et al. (1987a) studied diet selection by cattle on aeschynomene-limpograss pastures. Measurements taken in the first 20 min of grazing showed a quadratic relationship between percentage of legume in the diet and in the top 20 cm of the canopy. Cattle selected for the legume, but the relative differences between diet and canopy decreased as proportion of the legume in the canopy decreased. Reduction in selection for legume near the end of the grazing periods was indicated to be due to increasing herbage bulk density and decreasing leaf to stem ratios of the legume.

Techniques Used to Determine Diet Selection

Analysis of extrusa from esophageally-fistulated animals is considered the standard method of determining botanical composition of the diet (Laycock et al., 1972). Diet selection by resident animals on pasture is typically estimated from the composition of extrusa samples taken from fistulated animals that are placed on the pastures for short durations. Extrusa composition can be determined by either microscopic point quadrant (Heady and Torrell, 1959) or microhistological techniques (Sparks and Malechek, 1968), however, the correlation between diet compositions of fistulated and resident animals has sometimes been low (Coates et al., 1987). The low relationship is partially due to measurement of responses from fistulated animals over short periods of time and on small areas that may not be representative of the pasture as a whole.

A method often used in wildlife and range studies is to identify plant tissues microscopically and perform frequency counts of fragments for each species contained in samples of feces (Holechek et al., 1982). Sparks and Malechek (1968) validated the frequency count method reported by Fracker and Brischle (1944) for use with the microhistological analysis that was described by Baumgartner and Martin (1939) for identifying plant species in feces. Ground plant fragments were counted for 11 samples that contained known mixtures of six different species. Relative density of each species was calculated

from the frequency counts and observed to have a 1 to 1 relationship with the actual dry weight percentage. The technique was concluded to be a valid predictor of diet composition if it can be assumed that (1) the fragments of plants are randomly distributed on microscope slides, (2) fragments from different species are the same average size, and (3) dry weight bulk densities for the different species are the same.

Low discernability of highly digestible species is a recognized problem with the technique (Dearden et al., 1975; Vavra and Holechek, 1980). Thus, there is a possibility that components with high digestibilities will be underestimated and components with low digestibilities will be overestimated. Vavra et al. (1978) used microhistological analysis to compare measurements of botanical composition from extrusa and fecal samples from fistulated steers. The two compositions were poorly correlated, but paralleled in their ranking of individual species. Therefore, the technique was indicated to be of more value in qualifying the relative importance of species rather than quantifying their consumption.

CHAPTER THREE
MATERIALS AND METHODS

Research Site, Management, and Experimental Design

A grazing study was conducted at the Ona Agricultural Research and Education Center located in south-central Florida (27° 26' N latitude, 82° 55' W longitude). The research site was located on soils of the Pomona Series (sandy, siliceous, hyperthermic Ultic Haplaquod).

Each of three 1.97-ha pastures of Pensacola bahiagrass were subdivided randomly into 1.0, 0.57, and 0.40 ha pastures to impose different stocking rates. The three replications of stocking rates were arranged in a randomized complete block design. The bahiagrass pastures were overseeded, following a light disking, in early March 1987 with a mixture of carpon desmodium, seeded at a rate of 10 kg ha^{-1}, aeschynomene, seeded at a rate of 20 kg ha^{-1} (10 kg of podded and 10 kg of depodded seed), and phasey bean, seeded at a rate of 10 kg ha^{-1}. Fertilization consisted of application of 22 kg P ha^{-1} and 83 kg K ha^{-1} in late March of 1987 and late May of 1988.

Pastures were grazed by cross-bred yearling steers (_Bos taurus_-_Bos indicus_) from 23 July to 3 Oct 1987 (SUM87), 26 March to 21 May (SPR88), and 14 July to 23

Sept. (SUM88) 1988. Summer grazing was during a period when legume contribution to pastures was highest, and spring grazing was allowed to restrict bahiagrass growth and reduce the competitiveness of the grass with legume growth. Stocking rates of 2.0, 3.5, and 5.0 animals ha^{-1} were imposed to exert light, moderate, and heavy grazing intensities on the mixture in SUM87 and SPR88. The stocking rates were increased in SUM88 to 3.0, 5.3, and 7.5 animals ha^{-1} to provide a heavier grazing intensity.

Sample Collection and Analyses of Plant Responses

Pasture Samples

Forage samples were randomly taken from pastures on seven sampling dates in SUM87 [0, 7, 14, 28, 42, 56, and 71 days of grazing (DOGR)] and three sample dates in SPR88 (0, 28, 56 DOGR) and SUM88 (0, 28, 71 DOGR). Herbage from ten 0.25 m^2 sites was clipped to ground level from each pasture in SUM87 and SPR88 at each sampling date. Productivity of aeschynomene and phasey bean was low in SUM88 and, thus, to improve detection of these legumes, 20 samples were clipped from each pasture during this grazing season. Sample sites were chosen using a grid system to prevent overlapping of sites. The samples were dried at 60° C, weighed, and ground to pass a 1-mm screen.

Prior to drying the pasture samples, two samples from each pasture in SUM87 and SPR88 and ten samples from each

pasture in SUM88 were hand-separated into bahiagrass, each legume, weeds, and dead herbage components. Weeds were primarily composed of common bermudagrass and sedges (Cyperaceae spp.). The hand-separated samples were dried at 60° C, weighed and combined back into the original composition and thoroughly mixed before grinding.

All hand-separated samples were analyzed for IVDOM and CP concentration. Samples were digested for N determination using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Ammonia in the digestate was determined by semiautomated colorimetry (Hambleton, 1977) and CP was calculated (N x 6.25) on a DM basis. In vitro digestible organic matter was determined using a modification of the two-stage technique described by Moore and Mott (1974).

Botanical composition, IVDOM, and CP concentration were predicted for samples of unknown composition and nutritive value using near infrared reflectance spectroscopy (NIRS). Hand-separated samples from the three seasons were combined to generate calibration and validation sets for predicting botanical composition. In vitro digestible organic matter and CP concentration were predicted for each season separately from the wet chemistry performed on the hand-separated samples. Reflectance was collected and processed by NIRS equipment and procedures similar to those described by Shenk et al. (1981). Optimum equations were detected by procedures described by Brown and Moore (1987).

Herbage mass (kg DM ha^{-1}) and herbage allowance [kg DM $(100\ kg\ BW)^{-1}$] were calculated as measures of available forage determined from the mean dry weight of green herbage in samples taken from each pasture. Botanical composition was calculated to provide percentage of each component in total legume (SLL and carpon desmodium), green herbage, and total herbage (green plus dead herbage).

Composition and concentration data were transformed (arcsine) for statistical analyses. Availability, nutritive value, and botanical composition each were analyzed among seasons for seasonal and stocking rate effects by examining the stocking rate effect as a multiple regression and detecting seasonal effects using dummy variables (Freund et al., 1986). The season x stocking rate interaction also was analyzed using a test for the heterogeneity of slopes (Freund et al., 1986). Mean responses were compared between seasons by the least squares means procedure (Freund et al., 1986). Days of grazing was analyzed within seasons as the sub-plot treatment in a split-plot design. Linear and quadratic responses to DOGR were detected using orthogonal contrasts. Responses to stocking rate were also analyzed using orthogonal contrasts when a significant ($P < 0.05$) stocking rate x DOGR interaction occurred. Correlation coefficients were calculated for each season to detect relationships of IVDOM and CP concentration of pasture herbage to components in the botanical composition.

Whole Plant Samples

Whole plants of each legume and vegetative tillers of bahiagrass were randomly chosen and clipped to ground level from each pasture. Aeschynomene plants were clipped in SUM87 at 1, 28, and 71 DOGR. Phasey bean was clipped at 1 and 28 DOGR, but plant numbers were substantially reduced and not sampled at 71 DOGR. Short-lived legumes were not sampled in SPR88 and SUM88 when plant populations were low. Carpon desmodium was clipped at 1, 28, and 71 DOGR in SUM88, when plant populations were sufficient to warrant sampling. Bahiagrass was clipped at 0, 28, and 56 DOGR during SPR88 and 0, 28, and 71 DOGR during SUM88.

Each legume was hand-separated into leaf and stem fractions. The samples were dried at 60° C, weighed, and ground to pass a 1-mm screen. Leaves and stems of the legumes and tillers (primarily leaves) of bahiagrass were analyzed for IVDOM and CP concentration as previously described.

Leaf to stem ratios (L/S) were determined for each legume from the dry weights of leaves and stems. Responses for each species were analyzed in a split-plot design by analyzing stocking rate effects as the main-plot treatment and DOGR as the sub-plot treatment (Steel and Torrie, 1980). Linear and quadratic responses to stocking rate and DOGR were detected using orthogonal contrasts.

Soil Seed Reserves

Twenty core samples of soil (.08 m^2) were taken from each pasture following flowering and seed dispersal in 1987 and 1988. Soil to a 2-cm depth was screened to collect all legume seed. Seeds were identified and counted for each legume. Mean soil seed reserves for each pasture were calculated on a per m^2 basis and transformed (reciprocal) to stabilize the unequal variances that resulted from large differences between treatment means. Stocking rate effects were analyzed in a randomized complete block design. Linear and quadratic reponses to stocking rate were analyzed using orthogonal contrasts.

Sampling and Analyses of Animal Responses

Animal Performance

Animals were weighed, following a 14-hr shrinkage period to minimize variation due to fill, on days 1, 28, and 71 in SUM87 and SUM88 for measurement of ADG during the two periods and the whole trial. In SPR88 animal weights were taken only at the initiation (day 1) and conclusion (day 56) of grazing.

Animal weight changes were used to calculate ADG and gain per hectare. Seasonal and stocking rate effects on ADG and gain per hectare were detected by analyzing stocking rates as a multiple regression and analyzing seasons using dummy variables (Freund et al., 1986). The

season x stocking rate interaction also was analyzed using a test for the heterogeneity of slopes (Freund et al., 1986). Average daily gain was compared among seasons by the least squares means procedure. Within seasons, period effects on ADG in SUM87 and SUM88 were analyzed as the sub-plot treatment in a split-plot design. Linear and quadratic responses to stocking rate were detected using orthogonal contrasts. Correlation coefficients were calculated for each season to detect relationships between ADG and pasture responses.

Diet Composition

Fecal samples were taken rectally from individual steers on days 28 and 71 during SUM87 and SUM88. The samples were dried at 60° C and ground to pass a 1-mm screen. Botanical composition of the fecal samples was determined by a microhistological technique that followed procedures described by Sparks and Malechek (1968), with the exception that fragments were examined at a magnification of 200X to improve the detection of legume fragments. Frequency counts were made on fragments identified as being from grass, SLL, or carpon desmodium. Count data were converted to relative densities using calculations described bed by Sparks and Malechek (1968).

Relative densities were transformed (arcsine) for statistical analyses. Seasonal and stocking rate effects on each component of the diet were analyzed by examining

stocking rate as a multiple regression and analyzing seasons using dummy variables (Freund et al., 1986). Within seasons, DOGR was analyzed for each component as a sub-plot treatment in a split-plot design (Steel and Torrie, 1980). Responses to stocking rate were analyzed using orthogonal contrasts when a significant ($P < 0.05$) stocking rate x DOGR interaction was observed.

Selectivity ratios (SELR) were calculated by a formula described by Taylor et al. (1980):

$$\text{SELR} = \frac{\text{\% component diet DM} - \text{\% component pasture DM}}{\text{\% component diet DM} + \text{\% component pasture DM}} \times 10$$

Ratios of +1 to +10 are ratings of selectivity while -1 to -10 are ratings of avoidance. Ratios of -1 to 1 indicate selection in proportion to pasture availability.

CHAPTER FOUR
RESULTS AND DISCUSSION: PLANT RESPONSES

Rainfall from April to June is crucial for the germination of seed and subsequent growth of tropical legumes, but rainfall is typically low during this period in south Florida. Rainfall recorded at the Ona AREC in 1987 and 1988 is shown in Table 4.1. Rainfall early in the growing season of 1987 was lower than the 45-year mean. Consequently, productivity of the legumes in 1987 was low. Rains in early July resulted in some germination and growth of aeschynomene and phasey bean, but plant populations were still low and somewhat scattered throughout the pastures.

Rainfall in 1988 tended to be above the 45-year average for most months in the growing season. Heavy rainfall in July, August, and early September resulted in substantial flooding in the pastures over much of the summer.

Botanical Composition

Evaluations of Botanical Composition

The standard errors and coefficients of determination for the NIRS validation and calibration sets used in predicting botanical composition are given in Table 4.2. The standard error of calibration for each component in

Table 4.1. Precipitation for 1987 and 1988 at the Ona Agricultural Research and Education Center.

Month	1987	1988	45-yr Mean
		mm	
Jan.	103	44	52
Feb.	43	92	66
Mar.	198	138	79
Apr.	3	12	57
May	71	87	101
June	78	219	212
July	263	288	225
Aug.	173	324	212
Sept.	72	217	183
Oct.	131	49	82
Nov.	86	43	48
Dec.	11	23	47
Total	1232	1536	1364

Table 4.2. Calibration and validation measures for NIRS† analysis of botanical composition.

Component	Calibration (n=140) Math treat-ment‡	λ	SEC§	R^2	Validation (n=139) Mean bias	SEA¶	r^2
			%		%	%	
Bahiagrass	2	8	9.61	0.76	-0.64	8.07	0.82
Aeschynomene	2	4	1.69	0.14	-0.17	1.95	0.13
Phasey bean	2	7	1.02	0.22	-0.07	0.93	0.43
Short-lived†† legumes	2	5	2.08	0.20	-0.20	2.14	0.31
Carpon desmodium	1	7	3.98	0.81	-0.78	3.40	0.81
Weeds	1	6	4.51	0.48	-0.21	4.65	0.46
Dead	2	5	9.36	0.80	0.10	8.04	0.83

† NIRS = near infrared reflectance spectroscopy.
‡ Mathematical treatment: 1 = first derivative, 2 = second derivative.
λ Number of wavelengths in equation.
§ Standard error of calibration.
¶ Standard error of analysis.
†† Aeschynomene and phasey bean.

the composition was acceptable. Coleman et al. (1985) reported that major components of a pasture mixture can acceptably have standard errors of calibration as high as 11%. Bias, which is the average deviation of predicted values from actual values in the validation set, was below 1.0% for each component which indicated adequate prediction was achieved. Low percentages of aeschynomene and phasey bean in the samples resulted in the coefficients of determination being low for the calibration and validation sets. To minimize error in detection, aeschynomene and phasey bean were combined and analyzed as the SLL.

Green Herbage

Days of Grazing. Composition of green herbage over DOGR is shown for SUM87 and SPR88 in Figs. 4.1 and 4.2, respectively. Carpon desmodium increased over DOGR in SUM87, but not in SPR88 and SUM88. Short-lived legumes decreased in percentage of green herbage in SUM87, but were constant over DOGR in SPR88 and SUM88. Bahiagrass increased in SPR88, when growth rate of the grass was high towards the latter part of the season.

Seasonal Effects. Composition of green herbage is shown for each season in Fig. 4.3. Percentages for bahia-grass and weeds did not differ among seasons. The weed component was primarily composed of bermudagrass. Lack

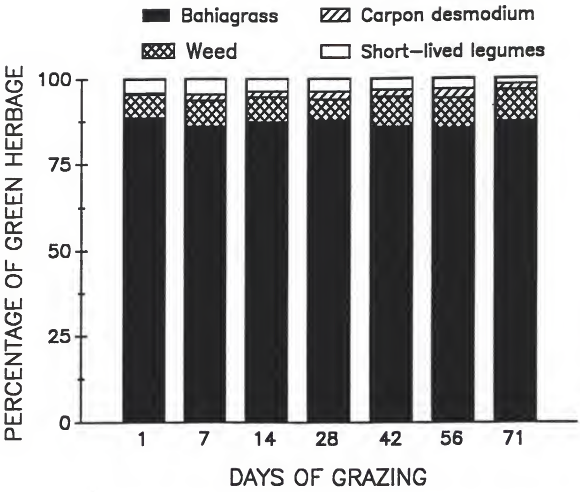

Fig. 4.1. Botanical composition of green herbage over days of grazing in the summer of 1987 [carpon desmodium: linear ($P < 0.001$) and quadratic ($P < 0.001$) responses; short-lived legumes: linear ($P < 0.001$) and quadratic ($P < 0.003$) responses].

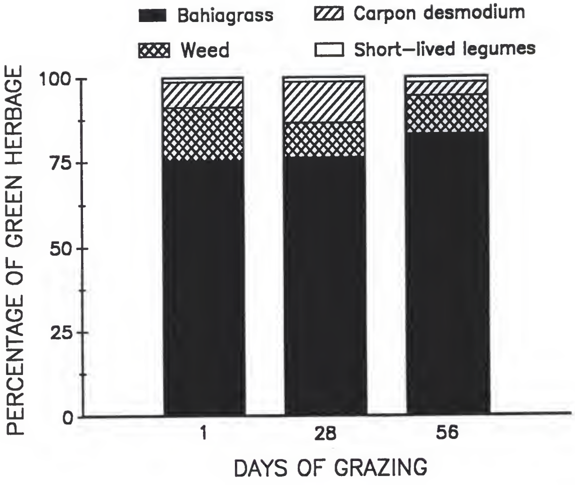

Fig. 4.2. Botanical composition of green herbage over days of grazing in the spring of 1988 [bahiagrass: linear ($P < 0.006$) response; carpon desmodium: linear ($P < 0.002$) and quadratic ($P < 0.001$) responses; weed: linear ($P < 0.06$) response].

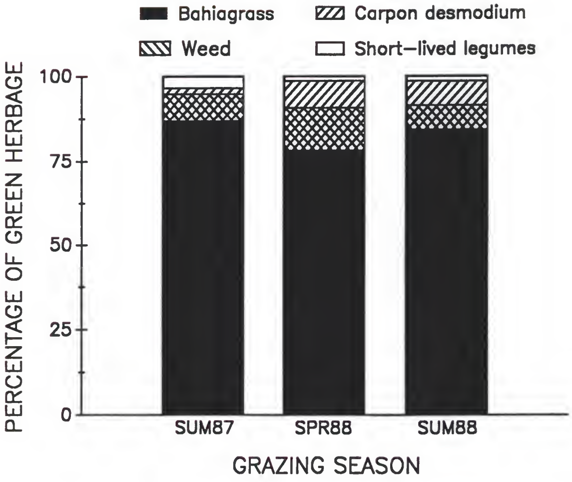

Fig. 4.3. Botanical composition of green herbage in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988 [percentage differences between seasons: carpon desmodium - SUM87 < SPR88 ($P < 0.001$), SUM87 < SUM88 ($P < 0.001$); short-lived legumes - SUM87 > SPR88 ($P < 0.01$), SUM87 > SUM88 ($P < 0.05$)].

of increase in bermudagrass percentage indicated that bermudagrass was not overly competitive with bahiagrass.

Percentages of carpon desmodium and SLL in green herbage both changed between seasons. Carpon desmodium was low in SUM87, but increased in SPR88. Percentage carpon desmodium was similar between SPR88 and SUM88. Short-lived legumes were highest in SUM87, but were at similar low percentages in SPR88 and SUM88.

Stocking rate. Stocking rate did not affect ($P > 0.10$) any component of the green herbage of pastures when seasons were combined. However, botanical composition was highly variable among pastures.

Composition of Total Legume

Days of Grazing. Total legume was composed of two components, and trends in percentage of SLL were opposite those of carpon desmodium. Changes in composition of the legume component of pastures in SUM87 and SPR88 are illustrated in Figs. 4.4 and 4.5, respectively. Short-lived legumes were highest as a percentage of total legume at the initiation of grazing. Short-lived legumes decreased sharply by 7 DOGR, with more gradual declines being observed over the remainder of the season. Reductions of SLL through the season suggest that these legumes were grazed to a degree that affected their recovery from defoliation and subsequent growth.

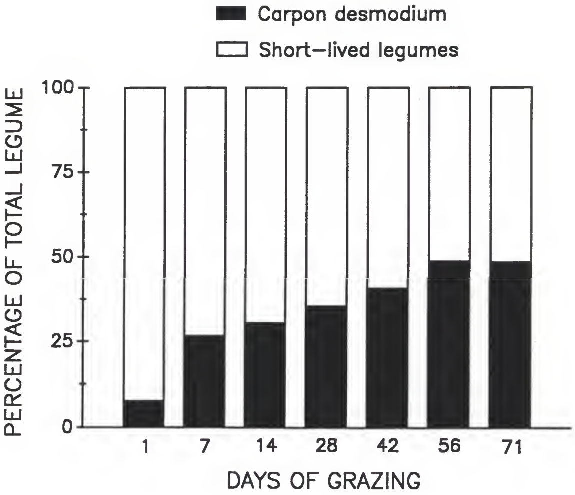

Fig. 4.4. Responses to days of grazing for percentages of carpon desmodium and short-lived legumes in total legume for the summer of 1987 [linear ($P < 0.001$) and quadratic ($P < 0.04$) responses].

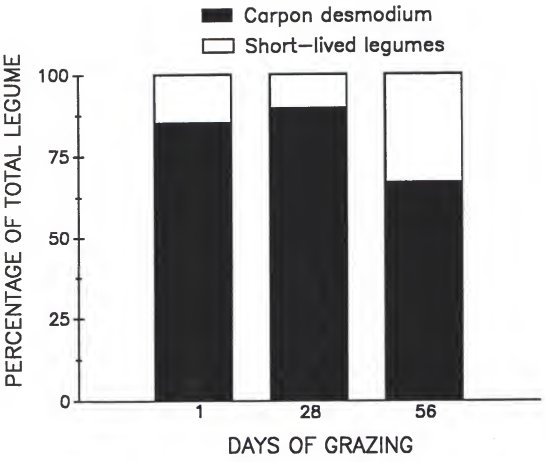

Fig. 4.5. Responses to days of grazing for percentages of carpon desmodium and short-lived legumes in total legume for the spring of 1988 [linear ($P < 0.001$) and quadratic ($P < 0.001$) responses].

Populations of phasey bean were observed to decline dramatically as grazing progressed through the season. This would agree with reports of other studies (Brolman and Kretschmer, 1973; Pitman, 1983) that showed the legume to lack persistence under grazing. Carpon desmodium became more competitive as the season progressed, which was indicated by the declines of SLL as a proportion of the total legume. Early in the season, carpon desmodium tended to be low in the canopy and growth was minimal. Growth of carpon desmodium may have been enhanced as the bahiagrass canopy was grazed to lower levels through the season.

Total legume changed in composition over days of grazing in SPR88. Percentage of SLL in total legume was low at 1 and 28 DOGR. Percentage SLL was low in the pasture botanical composition and likely of low accessibility to animals. Carpon desmodium was similarly of low percentage but tended to contribute more DM to pastures.

Short-lived legumes in SUM88 were primarily composed of aeschynomene with only a negligible number of phasey bean plants being observed in pastures. Short-lived legume percentage did not change over days of grazing in SUM88, which was likely due to the scattered distribution of plants in pastures. This could have limited the potential for selective grazing and allowed for longer rest periods for individual plants between defoliations. The waterlogging that was prevalent in this period also may have provided a more suitable environment for SLL growth and

persistence. Carpon desmodium in SUM88 was high in percentage of total legume and constant over DOGR, which indicated that the legume is tolerant of continuous grazing.

Stocking Rate. Stocking rate did not affect ($P = 0.47$) composition of total legume when seasons were combined. However, there was a linear decrease ($P < 0.02$) in SLL as a percentage of total legume and a corresponding linear increase in carpon desmodium with increases in stocking rate in SUM87 (Figure 4.6). Short-lived legumes decreased in percentage of total legume as defoliation progressed under heavier stocking rates. The higher percentage of carpon desmodium observed as stocking rate increased was probably caused by a reduction in canopy height which allowed the legume to be more competitive. High concentrations of immature carpon desmodium plants were observed late in the season in areas of pastures that had been closely grazed.

Stocking rate also did not affect legume composition in SPR88 ($P = 0.88$) or SUM88 ($P = 0.54$). As previously discussed, the dispersed legume populations and waterlogging in SUM88 may have been conducive to survival of SLL. Carpon desmodium appeared to be tolerant of the range of grazing intensities imposed in this season. This agrees with results of a study conducted by Pitman et al.

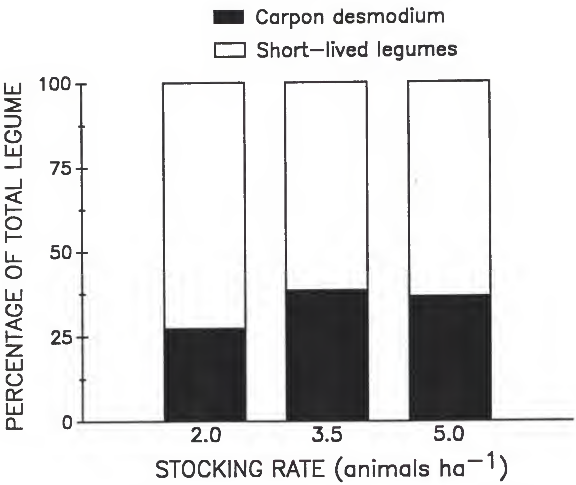

Fig. 4.6. Responses to stocking rate for percentages of carpon desmodium and short-lived legumes in total legume for the summer of 1987 [linear ($P < 0.02$) response].

(1988) that showed that carpon desmodium persisted under both light and heavy stocking rates.

Seasonal Effects. Composition of total legume for each season is shown in Figure 4.7. Slow establishment of carpon desmodium resulted in the legume contributing little DM to pastures in SUM87. The legume was observed to contribute more DM to pastures towards the end of SPR87. A tolerance to water deficits (Kretschmer et al., 1979) allowed carpon desmodium to survive low moisture during the late spring and early summer and become established prior to initiation of grazing in SUM88. However, performance of the legume was erratic among pastures. Percentage of carpon desmodium in total legume did not differ ($P = 0.73$) between SPR88 and SUM88, but percentages in both seasons were higher ($P < 0.001$) than in SUM87.

Conversely, SLL contributed the most to total legume in SUM87. Grazing was ceased after first flowering of aeschynomene had occurred in late September in SUM87. Higher percentages for aeschynomene might have been provided in SPR87 and SUM88 had the legume not been grazed for part of the flowering period. However, forage supply, was the criteria used in determining length of grazing in order to provide an environment that would enhance carpon desmodium establishment.

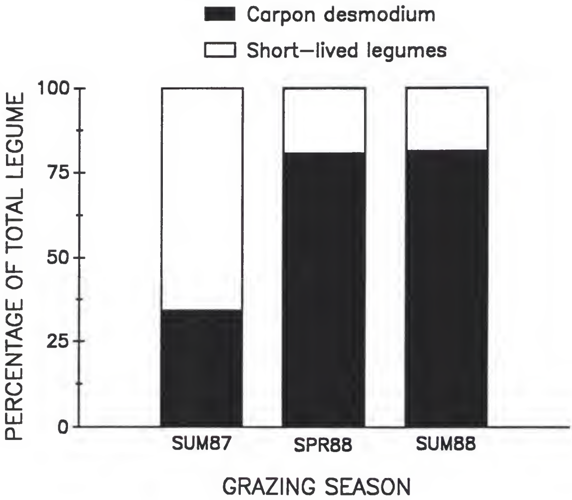

Fig. 4.7. Percentages of carpon desmodium and short-lived legumes in total legume in the summer of 1987, and the spring and summer of 1988 [percentage differences between seasons: carpon desmodium - SUM87 < SPR88 ($P < 0.001$), SUM87 < SUM88 ($P < 0.001$); Short-lived legumes - SUM87 > SPR88 ($P < 0.001$), SUM87 > SUM88 ($P < 0.001$)].

Available Forage

Herbage Mass

Days of Grazing. Herbage mass in SUM87 was affected ($P < 0.02$) by a stocking rate X DOGR interaction (Table 4.3). Herbage mass was not affected by stocking rate until 14 DOGR, when herbage declined linearly with increases in stocking rate. Differences in herbage mass were small between the moderate and heavy stocking rates until 42 DOGR. Herbage for the moderate and heavy stocking rates declined linearly over the season while herbage for the light stocking rate did not show large declines until after 42 DOGR.

Herbage mass in SPR88 also was influenced ($P < 0.03$) by a stocking rate x DOGR interaction (Table 4.4). A stocking rate effect on herbage mass was not detected until 28 DOGR. Differences in herbage mass between the moderate and light rates were evident at 28, but not 56 DOGR. There was a curvilinear increase in herbage mass for the light stocking rate over DOGR, while herbage mass for the moderate and heavy stocking rates was not affected by DOGR.

The stocking rate x DOGR interaction for herbage mass was less pronounced ($P = 0.055$) in SUM88. A carry over effect on herbage from grazing in SPR88 resulted in some differences among stocking rates in herbage mass at the beginning of SUM88. Herbage levels at the initiation of

Table 4.3. Stocking rate x days of grazing (DOGR) interaction for herbage mass in the summer of 1987.

	Stocking rate†				
DOGR	2.0	3.5	5.0	SE‡	Response§
	kg DM ha^{-1}				
1	3331	3035	3057	135.5	NS
7	2927	3138	3205	219.5	NS
14	3221	2601	2707	142.0	L*
28	2985	2522	2404	134.3	L
42	2964	2382	2122	114.8	L*,Q*
56	2391	2028	1789	86.6	L*,Q*
71	1971	1692	1254	158.2	Q*
SE	136.7	113.8	127.9		
Response	L***,Q*	L***	L***		

† Animals ha^{-1}.
‡ Standard error of a treatment mean.
§ NS = not significant. Linear (L) or quadratic (Q) response with probability $P < 0.001$(***), $P < 0.05$ (*), or $P < 0.10$ (letter listed, but not followed by a superscript).

Table 4.4. Stocking rate x days of grazing (DOGR) interaction for herbage mass in the spring of 1988.

	Stocking rate†				
DOGR	2.0	3.5	5.0	SE‡	Response§
	kg DM ha^{-1}				
1	1268	1185	1079	153.5	NS
28	1735	1311	949	115.9	L, Q*
56	1818	1194	1147	70.2	L**,Q*
SE	77.1	89.7	105.7		
Response	L***,Q*	NS	NS		

† Animals ha^{-1}.
‡ Standard error of a treatment mean.
§ NS = not significant. Linear (L) or quadratic (Q) response with probability $P < 0.001$(***), $P < 0.05$ (*), or $P < 0.10$ (letter listed, but not followed by a superscript).

grazing for light, moderate, and heavy grazing intensities were 3239, 3052, and 2756 kg DM ha-1, respectively. Decreases in herbage mass between 28 and 71 DOGR were of a lower magnitude than those between 1 and 28 DOGR (Table 4.5).

Stocking Rate. The relationship between stocking rate and herbage mass for each season is illustrated in Fig. 4.8. Herbage mass declined linearly ($P < 0.001$) with increases in stocking rate when seasons were combined. The test for the heterogeneity of slopes indicated that herbage mass responded similarly ($P = 0.89$) to stocking rate. However, the relationship when analyzed within seasons was significant only for SUM88. The magnitude of stocking rates used in SUM87 and SPR88 may have been too low to provide a desirable range of herbage masses.

Seasonal Effects. Herbage mass did not differ ($P = 0.88$) between the two summer seasons, but both of these seasons were higher ($P < 0.001$) in herbage mass than SPR88. Grazing in SPR88 was during a period when bahiagrass was initiating growth. Thus, accumulation of DM prior to the trial was minimal. Contribution of legumes to pastures also was low until the latter part of the season when the legumes initiated growth. Furthermore, preceding the two summer seasons the pastures had long rest periods which allowed substantial accumulation of DM to occur prior to grazing.

Table 4.5. Herbage mass and herbage allowance responses to days of grazing (DOGR) in the summer of 1988.

DOGR	Herbage mass	Herbage allowance
	kg DM ha^{-1}	kg DM (100 kg $BW)^{-1}$
1	3016	238
28	2012	166
71	1583	131
SE†	139.6	12.5
Response‡	L***,Q**	L***,Q**

† Standard error of a treatment mean.
‡ NS = not significant. Linear (L) or quadratic (Q) effect with probability $P < 0.001$(***), $P < 0.01$(**).

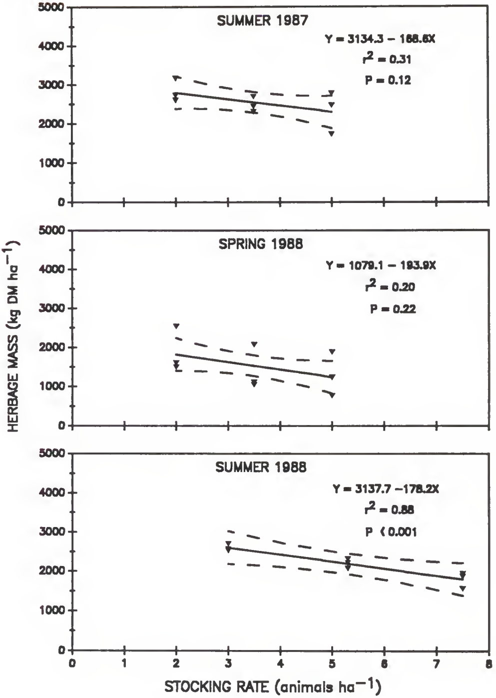

Fig. 4.8. Regression of herbage mass on stocking rate for the summer of 1987, and the spring and summer of 1988 (——— regression line, - - - 95% confidence band).

Herbage Allowance

Days of Grazing. A stocking rate x DOGR interaction for herbage allowance was detected ($P < 0.007$) in SUM87 (Table 4.6). Differences in herbage allowance were greater between the light and moderate stocking rates than between the moderate and heavy rates for each DOGR. Similar to herbage mass in this season, herbage allowance decreased linearly with DOGR for the moderate and heavy stocking rates, but herbage allowance did not start declining on the light stocking rate until after 42 DOGR. Linear declines in herbage allowance for the moderate and heavy stocking rates indicate that pasture growth rates were below the DM intake demands of the animals. Intake on the light stocking rate was apparently similar to pasture growth rates until after 42 DOGR. This was in the latter part of the season when night temperatures can drop to levels that limit bahiagrass growth.

A stocking rate x DOGR interaction also was observed ($P < 0.002$) for herbage allowance in SPR88 (Table 4.7). Differences in herbage allowance were greater between the light and moderate stocking rates than between the moderate and heavy rates for each DOGR at 1, 28, and 56 DOGR. There was a quadratic increase in herbage allowance for the light stocking rate, but no changes in herbage allowance for the moderate and heavy stocking rates were observed ($P > 0.10$).

Table 4.6. Stocking rate x days of grazing (DOGR) interaction for herbage allowance in the summer of 1987.

DOGR	Stocking rate† 2.0	3.5	5.0	SE‡	Response§
	kg DM (100 kg BW)$^{-1}$				
1	575	304	217	16.5	L***,Q***
7	505	316	227	19.2	L**,Q**
14	556	254	190	14.8	L***,Q***
28	514	254	170	14.8	L***,Q***
42	511	239	150	10.9	L***,Q***
56	412	202	126	6.3	L***,Q***
71	342	169	88	21.3	L**,Q**
SE	22.7	12.8	8.5		
Response	L***,Q*	L***	L***		

† Animals ha^{-1}.
‡ Standard error of a treatment mean.
§ NS = not significant. Linear (L) or quadratic (Q) response with probability P < 0.001(***), P < 0.01 (**), or P < 0.05 (*).

Table 4.7. Stocking rate x days of grazing (DOGR) interaction for herbage allowance in the spring of 1988.

	Stocking rate†				
DOGR	2.0	3.5	5.0	SE‡	Response§
	—kg DM (100 kg BW)$^{-1}$—				
1	264	138	88	16.7	L*,Q*
28	361	153	78	12.3	L***,Q***
56	379	139	94	14.7	L***,Q***
SE	16.0	10.4	8.7		
Response	L*,Q	NS	NS		

† Animals ha^{-1}.
‡ Standard error of a treatment mean.
§ NS = not significant. Linear (L) or quadratic (Q) response with probability $P < 0.001$(***), or $P < 0.05$ (*), or $P < 0.01$ (letter listed, but not followed by a superscript).

Intake under the light stocking rate was evidently below pasture growth rates. A lack of response for herbage under moderate and heavy stocking rates would suggest that intake was in equilibrium with pasture growth rates.

The lack of a stocking rate x DOGR interaction ($P = 0.10$) for herbage allowance in SUM88 indicates that the three stocking rates generally responded to DOGR in a similar manner. Herbage allowance declined most between 1 and 28 DOGR (Table 4.5), which indicated that grazing during the early part of the season was primarily of excess forage that had accumulated prior to grazing.

Pastures at the light stocking rate in each season were observed to be under-utilized. Spot grazing was not pronounced, which is interesting since intense spot grazing in commonly observed on under-utilized bahiagrass (Hodges, 1976). Mixing legumes with bahiagrass might reduce spot grazing by providing animals with accessible, high quality legumes. Pastures under the heavy stocking rate were void of areas that contained accumulated, under-utilized forage. The closeness of grazing indicated that these pastures were over-grazed. However, based on forage supply at the conclusion of the three seasons, the heavy stocking rate could have carried animals for a longer period before available forage became severely limited.

<u>Seasonal Effects</u>. Differences in herbage allowance between seasons paralleled those observed for herbage mass. Herbage allowance did not differ ($P = 0.40$) between the two

summer seasons, but both of these seasons were higher ($P < 0.001$) in herbage allowance than SPR88.

Leaf to Ratio Ratio and Nutritive Value of Individual Species

Short-Lived Legumes

Aeschynomene. Stocking rate did not affect ($P > 0.10$) the nutritive value of aeschynomene in SUM87, but there was an effect of DOGR (Table 4.8). Leaf to stem ratios declined linearly from 1 (23 July) to 71 (20 Aug.) DOGR. This response was a reflection of leaf removal by animals and increases in the size and density of stems from morphological development and lignification during the growing season. In vitro digestible organic matter was initially high in leaves and declined slightly over the season. Leaf CP concentration declined after 28 (3 Oct.) DOGR. Highest IVDOM and CP concentration for aeschynomene have been shown to be in the upper, more leafy part of the plant (Hodges and McCaleb, 1972; Mislevy and Martin, 1985). Removal of top leaves, which can be extensive under continuous grazing, exposes lower leaves with nutritive values that are affected by prior shading. Although IVDOM and CP concentration declined over the season, they were still relatively high at the end of the season and at levels that would be expected to provide good animal performance.

In vitro digestible organic matter in stems was initially low and declined through the growing season.

Table 4.8. Responses of leaf to stem ratio (L/S), in vitro digestible organic matter (IVDOM), and crude protein (CP) concentration to days of grazing (DOGR) for aeschynomene and phasey bean in the summer of 1987.

Legume	DOGR	L/S	IVDOM leaf	IVDOM stem	CP leaf	CP stem
			g kg^{-1} OM		g kg^{-1} DM	
Aeschynomene	1	0.86	779	446	235	78
	28	0.70	755	399	248	74
	71	0.41	718	386	219	72
	SE†	0.10	10.9	15.8	10.9	8.9
	Response‡	L***	L***,Q	L***,Q	L,Q*	NS
Phasey bean	1	1.37	752	598	226	89
	28	0.76	755	547	233	85
	SE	0.20	13.8	8.9	8.7	5.0
	F test¶	*	NS	***	NS	NS

† Standard error of a treatment mean.
‡ NS = not significant. Linear (L) and quadratic (Q) response with probability $P < 0.001$(***), or $P < 0.05$ (*) or $P < 0.10$ (letter listed, but not followed by a superscript).
¶ Significant at $P < 0.001$ (***) and $P < 0.05$ (*), respectively, NS = $P > 0.10$.

This was probably due to increasing lignification, but IVDOM was measured for stems clipped to ground level and may not be related to portions of stems in the upper region of the canopy that were more herbaceous and most often defoliated by animals. Crude protein concentration of stems was low and remained constant over the season.

Phasey Bean. Stocking rate did not affect ($P > 0.10$) the nutritive value of phasey bean in SUM87, but some responses did change over DOGR (Table 4.8). Leaf to stem ratio was initially high. This is a reflection of the leafiness of the plant and the hollow, herbaceous stems in the upper regions of the plant. Decreases in L/S ratio were observed from 1 to 28 DOGR. Dramatic declines in plant populations were obvious by 28 DOGR and plants that were sampled were typically void of the upper, leafy regions that had been removed by animals.

Levels of IVDOM and CP in leaves did not change from 1 to 28 DOGR. This would indicate that the nutritive value of phasey bean is maintained through the season, but sampling later in the season might have shown effects similar to those for aeschynomene.

In vitro digestible organic matter of stems decreased from 1 to 28 DOGR. This may have resulted from the woody part of the stem at the base of plants being a higher proportion of the total stem for plants sampled at 28 DOGR. Stem CP concentration was similar between 1 and 28 DOGR.

Carpon Desmodium

Stocking rate did not affect (P > 0.10) IVDOM or CP concentration of carpon desmodium in SUM88, but the nutritive value measurements did change over DOGR (Table 4.9). Leaf to stem ratio decreased from 1 (14 July) to 28 (13 Aug.) DOGR, but remained relatively constant for the remainder of the season. Initial decreases in L/S were primarily due to leaf removal by animals, and increases in density of stems.

Leaf IVDOM increased linearly from 1 to 71 (23 Sept.) DOGR. A depressing effect of tannins on IVDOM may have been indicated by the low IVDOM of this legume. Crude protein concentration in leaves increased over the season.

In vitro digestible organic matter and CP concentration for stems decreased between 1 and 28 DOGR, but increased between 28 and 71 DOGR. Regrowth of defoliated plants in the late season resulted in a higher portion of herbaceous, relatively immature stems. Plants sampled at 28 DOGR may not have recovered from initial defoliations, while growth may have been stimulated in the latter part of the season.

Bahiagrass

Stocking rate did not affect (P > 0.10) bahiagrass nutritive value, but levels did change over DOGR in SPR88 and SUM88 (Table 4.10). In vitro digestible organic matter

Table 4.9. Responses of leaf to stem ratio (L/S), in vitro digestible organic matter (IVDOM), and crude protein (CP) concentration to days of grazing (DOGR) for carpon desmodium in the summer of 1988.

		IVDOM		CP	
DOGR	L/S	leaf	stem	leaf	stem
		$g\ kg^{-1}$ OM		$g\ kg^{-1}$ DM	
1	0.77	442	368	168	65
28	0.42	454	310	172	49
71	0.49	513	350	188	59
SE†	0.09	21.6	17.1	10.7	4.5
Response‡	L**,Q**	L**	Q**	L	Q**

† Standard error of a treatment mean.
‡ NS = not significant. Linear (L) and quadratic (Q) response with probability $P < 0.01$(**), or $P < 0.10$ (letter listed, but not followed by a superscript).

Table 4.10. Responses of in vitro digestible organic matter (IVDOM) and crude protein (CP) concentration for bahiagrass to days of grazing (DOGR) in the spring (SPR88) and summer (SUM88) of 1988.

Season	DOGR	IVDOM	CP
		g kg^{-1} OM	g kg^{-1} DM
SPR88	1	508	93
	28	532	109
	56	520	93
	SE†	7.8	4.4
	Response‡	Q**	Q***
SUM88	1	499	59
	28	520	64
	71	517	80
	SE	13.3	5.1
	Response	NS	L***

† Standard error of a treatment mean.
‡ NS = not significant. Linear (L) and quadratic (Q) response with probability $P < 0.001$ (***), or $P < 0.01$ (**).

and CP concentration in SPR88 increased between 1 (26 Mar.) and 28 (23 Apr.) DOGR. Low temperatures in the early part of the season probably resulted in accumulations of starch and N. However, accelerated growth that occurred between 28 and 71 (21 May) DOGR resulted in reductions in IVDOM and CP concentration. Crude protein concentration through the season was above 70 g kg^{-1} DM reported by Minson (1980b) to be the minimum before intake is depressed.

In vitro digestible organic matter did not change over DOGR in SUM88. This is in disagreement with a report by Sollenberger et al. (1988) that concluded that IVDOM of continuously grazed bahiagrass will decrease through the season. Crude protein concentrations were low in SUM88, but increased through the season. Nitrogen absorption may have increased for bahiagrass as soils became less water-logged towards the end of the season.

Nutritive Value of Total Herbage

Measurements of Nutritive Value

The standard errors and coefficients of determination for the NIRS calibration and validation sets used in predicting IVDOM and CP concentration for each season are given in Table 4.11. Standard errors and coefficients of determination for predicting IVDOM were similar to those reported by Brown and Moore (1987) for pasture samples of limpograss harvested at different times.

Table 4.11. Calibration and validation measures for NIRS† analysis of in vitro digestible organic matter (IVDOM) and crude protein (CP) concentration for pasture samples in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

		Calibration					Validation			
Season	Fraction	Math treat- ment δ	λ	n	SEC¶	R^2	n	Bias	SEA#	r^2
SUM87	IVOMD	2	4	80	19.0	0.83	41	-1.7	20.1	0.79
	CP	1	3	80	2.8	0.87	41	-1.0	2.7	0.93
SPR88	IVOMD	2	4	98	23.5	0.71	41	-2.6	24.0	0.76
	CP	1	3	98	6.2	0.50	41	-0.4	4.6	0.84
SUM88	IVOMD	2	4	123	24.9	0.78	123	2.9	20.8	0.83
	CP	0	7	123	4.7	0.65	123	0.0	4.3	0.67

† NIRS = near infrared reflectance spectroscopy.
δ Mathematical treatment: 0 = log (1/reflectance), 1 = first derivative, 2 = second derivative.
λ = number of wavelengths in equations.
¶ Standard error of calibration.
# Standard error of analysis.

Standard errors for validation and calibration for predicting CP concentrations were in an acceptable range, but the coefficients of determination were lower than desired for validation in SUM88 and calibration in SUM87 and SPR88. Brown and Moore (1987) observed similar low values for sample sets with low ranges of CP.

In Vitro Digestible Organic Matter

Days of Grazing. Responses to DOGR were obtained for IVDOM in each of the three seasons (Table 4.12). In vitro digestible organic matter in SUM87 began to decline following 14 DOGR, which paralleled increases in dead herbage (Table A.2). Linear increases in IVDOM were observed in SPR88 when bahiagrass increased in proportion relative to dead herbage. In vitro digestible organic matter in SUM88 showed a decline at 28 DOGR which was followed by a smaller decline at 71 DOGR. Reductions of green herbage by animal consumption and senescence of bahiagrass evidently caused the proportion of dead herbage to increase in both summer seasons.

Stocking Rate. There was no stocking rate effect on IVDOM for SUM87 ($P = 0.32$) or SPR88 ($P = 0.25$). A positive effect ($P < 0.05$) was detected for stocking rate in SUM88 ($Y = 359.2 + 4.2X$; $r^2 = 0.43$), which was probably the result of higher proportions of regrowth under the heavy intensity. As grazing intensity increased in this trial growth of bahiagrass appeared to be more vigorous. The

lower range of grazing intensities in SUM87 and SPR88 mayhave not produced enough difference in the swards to cause such a response.

Seasonal Effects. In vitro digestible organic matter of total herbage in SPR88 was higher than in SUM87 ($P < 0.001$) or SUM88 ($P < 0.02$). Between the two summer seasons, IVDOM was higher ($P < 0.001$) in 1988 than in 1987.

Differences in IVDOM between seasons were related to differences in pasture botanical composition in each season (Table 4.13). In SPR88, IVDOM was positively correlated with bahiagrass percentage. Bahiagrass was in an immature stage of growth for most of the season. In vitro digestible organic matter was negatively correlated with dead herbage percentage, but dead herbage decreased in proportion as bahiagrass percentage increased over DOGR (Table A.2). The relationships in SUM88 were similar to those detected for SPR88. In vitro digestible organic matter in SUM87 also was correlated with bahiagrass and dead herbage and was further positively correlated with percentages of SLL.

Crude Protein Concentrations

Days of Grazing. Responses for crude protein concentration over DOGR were not significant in each of the three seasons (Table 4.12). Persistence of the legume component through the summer seasons may have maintained CP concentrations higher than if bahiagrass had been the sole component.

Stocking Rate. Crude protein concentration was not affected by stocking rate in SUM87 ($P = 0.36$), SPR88 ($P = 0.70$), or SUM88 ($P = 0.20$). Again, persistence of the legumes under the three intensities in each season probably maintained CP concentrations higher than if bahiagrass had been the sole component.

Seasonal Effects. Total herbage in SUM87 was lower in CP concentration than in SPR88 ($P < 0.05$) or SUM88 ($P < 0.01$) when percentages of carpon desmodium were higher in the pasture composition. Crude protein concentrations did not differ ($P = 0.16$) between SPR88 and SUM88.

Crude protein concentration in SPR88 was not correlated with any of the pasture components (Table 4.13). Ranges of CP concentration and percentage for each component were low in this season. Crude protein concentration in SUM87 was positively correlated with SLL percentage, with similar correlations being observed between CP concentration and carpon desmodium percentage in SUM88. High CP concentration of the legumes in each season evidently had a positive effect on CP concentrations in total herbage. Crude protein concentration was negatively correlated with dead herbage in SUM88, and the high proportion of dead herbage in this season probably had a diluting effect on concentration of crude protein.

Table 4.12. Responses of in vitro digestible organic matter (IVDOM) and crude protein (CP) concentration for total herbage to days of grazing (DOGR) in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	DOGR	IVDOM	CP
		g kg^{-1} OM	g kg^{-1} DM
SUM87	1	383	72
	7	351	69
	14	352	69
	28	335	68
	42	311	68
	56	310	69
	71	296	69
	SE†	6.5	1.6
	Response‡	L***,Q***	L
SPR88	1	362	64
	28	397	68
	56	416	66
	SE	10.8	1.9
	Response	L***	L,Q
SUM88	1	435	65
	28	366	63
	71	342	63
	SE	4.7	1.0
	Response	L***,Q***	L

† Standard error of a treatment mean.
‡ Linear (L) and quadratic (Q) response with probability $P < 0.001$(***), or $P < 0.10$ (letter listed, but not followed by a superscript).

Table 4.13. Pearson correlation coefficients between pasture compositions ($n = 9$) and in vitro digestible organic matter (IVDOM) and crude protein (CP) concentration in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

	Season					
	SUM87		SPR88		SUM88	
Component	IVDOM	CP	IVDOM	CP	IVDOM	CP
Bahiagrass	0.84***	0.03	0.92***	0.05	0.90***	0.24
Carpon desmodium	-0.10	0.18	-0.09	0.16	0.10	0.68***
Short-lived legumes	0.71***	0.38**	0.37	0.22	0.15	0.13
Weeds	0.18	0.21	-0.32	0.26	0.30	0.04
Dead herbage	-0.94***	-0.34	-0.84***	-0.30	-0.93***	-0.45*

*, **, *** Significant at the $P < 0.05$, $P < 0.01$, $P < 0.001$ probability levels, respectively.

Soil Seed Reserves

Soil seed reserves of aeschynomene following the summers of 1987 and 1988, and of carpon desmodium following the summer of 1988 are shown in Table 4.14. A stocking rate effect was obtained for aeschynomene following grazing in SUM87. Although aeschynomene was grazed for a short time after first flowering had occurred, soil seed reserves were higher than expected for the light and moderate grazing intensities. These reserves were not of benefit to aeschynomene production in the following year, but litter and bahiagrass growth in the spring may have restricted the extent of germination and growth. Soil seed reserves were higher ($P < 0.08$) following SUM88 than following SUM87, which indicated there was a build-up of reserves of aeschynomene seed in the soil. An effect of stocking rate was not detected ($P = 0.41$) following SUM88. Seed reserves were highly erratic between pastures and reduced the sensitivity of detecting treatment effects.

Soil seed reserves for carpon desmodium following the summer of 1987 were in trace amounts. The higher productivity of carpon desmodium in SUM88 produced detectable amounts of seed. Similar to aeschynomene, seed reserves of carpon desmodium were higher than expected, but a stocking rate effect was not significant ($P = 0.28$). Similar to aeschynomene following SUM88, highly erratic seed reserves within treatments for carpon desmodium reduced the sensitivity of detecting treatment effects.

Table 4.14. Responses to stocking rate for soil seed reserves of carpon desmodium following the summer of 1988 (SUM88) and of aeschynomene following the summers of 1987 (SUM87) and 1988.

Season	SR	Legume	
		Carpon desmodium	Aeschynomene
	animals ha^{-1}	seed number m^2	
SUM87	2.0		575
	3.5		253
	5.0		3
	SE†		284.8
	Response‡		Q*
SUM88	3.5	281	2227
	5.3	757	1804
	7.5	193	134
	SE	328.8	1064.4
	Response	NS	NS

† Standard error of a treatment mean.
‡ NS = not significant. Linear (L) or quadratic (Q) response with probability $P < 0.05$ (*).

CHAPTER FIVE
RESULTS AND DISCUSSION: ANIMAL RESPONSES

Diet Composition

Measurements of Diet Composition

Plant fragments in the feces were identified as being grass, carpon desmodium, or short-lived legumes. The grass component was assumed to be primarily composed of bahiagrass, but distinctions were not made between fragments of bahiagrass and bermudagrass. Histological characteristics were quite similar between aeschynomene and phasey bean which made differentiation between the two legumes difficult. High digestibilities for the two legumes further caused their detection to be quite low. Therefore, fragments of the two legumes were identified as a combined component to improve detection. Conversely, the detection of carpon desmodium was reasonably high due to its relatively low digestibility and distinct characteristics.

Stocking Rate

Grass percentage in the diet was not influenced by stocking rate in SUM87 ($P = 0.25$) or SUM88 ($P = 0.28$). Thus, percentage of total legume in the diet also remained constant over stocking rates.

Percentage of SLL in the diet similarly was not affected by stocking rate in SUM87 ($P = 0.33$) or SUM88 ($P = 0.24$). Percentage of carpon desmodium in the diet decreased linearly ($P < 0.02$) with increases in stocking rate ($Y = 2.7 - 5.2X$; $r^2 = 0.78$) in SUM87. Although stocking rate did not affect percentage of carpon desmodium in the pasture composition, lower percentages of the legume in the diet suggest that accessibility of the legume was lower as grazing intensity increased. Percentage of carpon desmodium in the diet was not affected by stocking rate in SUM88 ($P < 0.24$).

Days of Grazing

Grass and SLL did not change in the diet composition between 28 and 71 DOGR in SUM87 (Table 5.1). A decrease between 28 and 71 DOGR was observed for carpon desmodium in SUM87. Accessibility of carpon desmodium was initially low in SUM87 but may have been reduced as grazing progressed through the season.

An increase in grass percentage was detected in the diets between 28 and 71 DOGR in SUM88. Percentage SLL in the diet decreased between 28 and 71 DOGR. Short-lived legumes were evidently less accessible on day 71 than on day 28.

Table 5.1. Effect of days of grazing (DOGR) on percentage grass, carpon desmodium (CD), and short-lived legumes (SLL) in the diet in the summers of 1987 (SUM87) and 1988 (SUM88).

Season	Component	DOGR 28	DOGR 71	SE†
		%		
SUM87	Grass	84.1	85.1	2.7
	CD‡	1.2	0.5	0.2
	SLL	14.5	14.4	2.9
SUM88	Grass***	88.4	90.5	0.4
	CD	6.0	6.6	0.7
	SLL**	5.5	2.9	0.5

† Standard error of a treatment mean.
***, **, ‡ Effect of DOGR with probability P < 0.001, P < 0.01, or P < 0.10, respectively.

Diet Selection

Trends in selection ratios over DOGR in SUM87 and SUM88 are shown for each component in Table 5.2. Grass was selected in proportion to its percentage in the green herbage in both seasons. This was not surprising because grasses were in extremely high proportion in the pasture.

Carpon desmodium was avoided in SUM87. A high portion of this legume was low in the canopy and may have been inaccessible to animals. Percentage carpon desmodium in green herbage was higher in SUM88, and selectivity ratios showed the legume to be selected in proportion to percentage in available forage. The selectivity ratios indicated that the palatability of carpon desmodium is evidently not high, but palatability does not appear to be low enough that the legume is avoided by animals. Furthermore, calculating the ratio using percentages of green herbage, rather than of the more accessible top layer of the canopy, may have resulted in some bias. Sollenberger et al. (1987a) reported that upper layer percentage aeschynomene in a limpograss-aeschynomene mixture explained the greatest portion of the variation in legume composition of the diet of esophageally-fistulated steers.

Selectivity ratios indicated that SLL were selectively grazed over both seasons. The short-lived legumes were evidently palatable and selected by animals over carpon desmodium and bahiagrass.

Table 5.2. Selectivity ratios† for grass, carpon desmodium (CD), and short-lived legumes (SLL) in the summers of 1987 (SUM87) and 1988 (SUM88).

Season	Component	DOGR 28	DOGR 71	SE‡
SUM87	Grass	0	0	0.2
	CD	-4	-5	2.1
	SLL	6	8	0.7
SUM88	Grass	0	0	0.1
	CD	0	0	1.1
	SLL	6	4	1.6

† Ratios of +10 and -10 are maximum selectivity and avoidance, respectively, while values of +1 to -1 indicates selection in proportion to percentage of available forage.
‡ Standard error of a treatment mean.

Animal Performance

Stocking Rate

Average Daily Gain. There was a negative linear effect ($P < 0.001$) of stocking rate on ADG when seasons were combined. This agrees with the linear relationship reported by Jones and Sandland (1974). The season x stocking rate interaction was not significant ($P = 0.71$), which indicated that responses to stocking rate had similar slopes among the seasons.

Effects of stocking rate on ADG within seasons were not significant in SUM87 (Fig 5.1). Although ADG was negatively related to stocking rate, the low range of stocking rates that were examined in both SUM87 and SPR88 may have resulted in only limited differences in intake within these seasons.

Stocking rate was negatively related to ADG in SUM88. Components of the diet were not affected by stocking rate, which suggests that the wider range of stocking rates used in this season resulted in reductions in intake as grazing intensity increased. Weight losses occurred on each of the three grazing intensities in SUM88, with losses of a high magnitude for the heavy grazing intensity. Extensive flooding through much of the season evidently had an adverse effect on intake, as well as the overall grazing behavior of the steers.

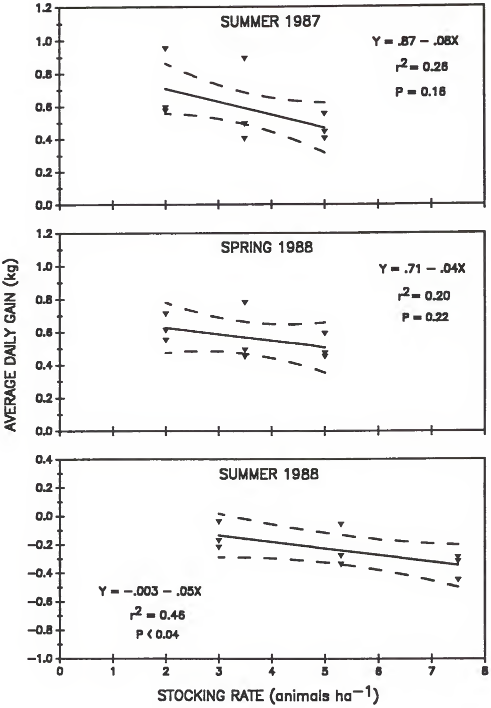

Fig. 5.1. Regression of average daily gain (ADG) on stocking in the summer of 1987, and the spring and summer of 1988 (——— regression line, - - - -95% confidence band).

Gain per hectare. A quadratic relationship was obtained between gain per hectare and stocking rate when seasons were combined. Gain per hectare tended to increase as stocking rate increased, except in SUM88, where weight loss per hectare increased with increases in stocking rate. This illustrates the potential for economic loss by Florida cattlemen who have pastures which are subjected to flooding over extended periods.

Stocking rate affected gain per hectare in SPR88 and SUM88, but gains were not affected in SUM87 (Fig 5.2). As previously discussed, the low range in stocking rates may not have precipitated substantial differences in diet quality and quantity. This could indicate that animal production on mixtures containing a high-quality legume may be associated more with legume persistence than with stocking rates. Although individual animal performance among seasons was inversely related to stocking rate, higher stocking rates in SUM87 and SPR88 indicated a potential to produce higher total gains. Gain per hectare increases as stocking rate is increased but starts to decline at a stocking rate that limits available forage. This relationship has been extensively reported in the literature (Mott, 1960; Petersen et al., 1965; Jones and Sandland, 1974).

Period Effects

There were significant period effects on ADG in SUM87 and SUM88 (Table 5.3). Average daily gain in SUM87 was

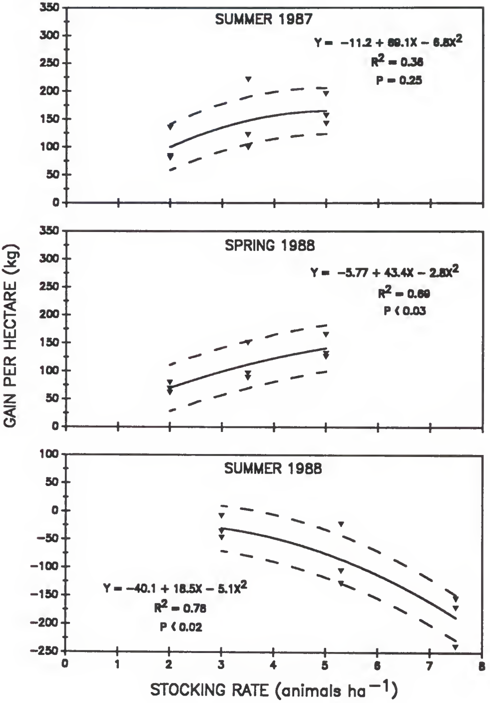

Fig. 5.2. Regression of gain per hectare on stocking rate in the summer of 1987, and the spring and summer of 1988 (——— regression line, - - - 95% confidence band).

Table 5.3. Effect of stocking rate (SR) on average daily gain for each period in the summers of 1987 (SUM87) and 1988 (SUM88).

Season	SR	Period†	
		1‡	2§
	animals ha^{-1}	kg	
SUM87	2.0	0.81	0.63
	3.5	0.89	0.40
	5.0	0.72	0.30
	SE¶	0.05	0.08
	Response††	Q	Q
SUM88	3.0	0.47	-0.60
	5.3	0.35	-0.66
	7.5	0.25	-0.80
	SE	0.10	0.80
	Response	NS	Q

† Main effect ($P < 0.001$) of period in SUM87 and SUM88.
‡ 28 d.
§ 43 d.
¶ Standard error of a treatment mean.
†† NS = not significant. Quadratic (Q) response with probability $P < 0.10$.

higher for period 1 (0.81 kg) than for period 2 (0.44 kg). Linear and quadratic effects were analyzed separately for each period since ADG was measured over a different number of days for each period. Although stocking rate effects on ADG over the season were not detected in SUM87, quadratic responses were shown for both periods. The quadratic response in period 1 was due to high ADG for steers on the moderate grazing intensity. Animal performance in period 2 was high for the light grazing intensity. Average daily gain for this period was similar to performance of yearling heifers reported by Pitman (1983) for a continuously-grazed bahiagrass-aeschynomene mixture under a stocking rate of 4 animals ha^{-1}. Although percentage of SLL in pastures was low in SUM87, SLL were in sufficient supply to be selectively grazed and to improve animal performance through the season. Lower ADG for the moderate and heavy grazing intensities suggests that intake became limited towards the later part of the season, but not to an extent that performance over the season was affected.

Weight gains were obtained during period 1 in SUM88. Flooding apparently had the most pronounced effect on animal performance in period 2. Average daily gain was not affected by stocking rate in period 1, but a quadratic relationship was detected for period 2. Weight losses were greater for the heavy grazing intensity than for the light and moderate ones.

Seasonal Effects

Average Daily Gain. Animal performance did not differ (P = 0.74) between SUM87 and SPR88. Poor animal performance in SUM88 resulted in ADG lower than in the other two seasons (P < 0.001). A lack of differences between SUM87, when SLL contribution to pastures was the highest, and SPR88 indicates that the immature stage of growth for bahiagrass in the spring was relatively high in quality.

Correlation coefficients between ADG and available forage (Table 5.4) show that animal performance increased with increases of herbage mass in both summer seasons and with increases of herbage allowance in SUMM88. Correlation coefficients between ADG and pasture composition show that animal performance was related to SLL in SUM87 and carpon desmodium in SUM88. Performance in SUM87 was negatively correlated with bahiagrass percentage, which could be expected when a mature grass is in a mixture with high-quality legumes. Although SLL percentages were low in the pasture composition in this season, they still had an effect on animal performance. Animal performance was positively correlated with carpon desmodium in SUM88. Carpon desmodium did not contribute high amounts of digestible organic matter, but it apparently contributed to the CP concentration of the mixture. Correlation of ADG with SLL would be expected for SUM88 since the selectivity for this component was high, but the component comprised

Table 5.4. Pearson correlation coefficients for average daily gain (n = 9) to forage availability, pasture botanical composition of green herbage, dead herbage, in vitro digestible organic matter (IVDOM), and crude protein (CP) concentration in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Variable	Season		
	SUM87	SPR88	SUM88
Herbage mass	0.69*	-0.18	0.85**
Herbage allowance	0.52	0.36	0.67*
Bahiagrass	-0.77*	0.04	0.55
Carpon desmodium	0.17	0.37	0.66*
Short-lived legumes	0.79*	-0.06	0.14
Weeds	0.74*	-0.22	-0.08
Dead herbage	0.18	0.31	-0.08
IVDOM	0.32	0.22	-0.35
CP	0.26	0.08	0.22

**, * Significant with probability $P < 0.01$ and $P < 0.05$, respectively.

only a negligible proportion of the pasture DM. This probably reduced the impact of the legume and perhaps the sensitivity of detecting the correlation. Average daily gain was not correlated with available forage or any component of the pasture in SPR88, but this may be due to a low range in animal performance that was observed for this season.

Gain Per Hectare. Differences in gain per hectare between seasons paralleled those of ADG. Gain per hectare did not differ between SUM87 and SPR88 ($P = 0.12$), but both were higher ($P < 0.001$) than the poor performance that was obtained for SUM88.

CHAPTER SIX
SUMMARY AND CONCLUSIONS

Botanical Composition

The first objective of this study was to determine seasonal and stocking rate effects on botanical composition of the mixture. A dramatic change in pasture composition occurred in the first season. Short-lived legumes had established prior to grazing, but the legumes were of a low percentage in pasture composition. Percentage of SLL decreased in percentage of green herbage as grazing progressed through SUM87. Carpon desmodium increased in percentage of green herbage as grazing progressed.

Plant populations of SLL were low and widely dispersed in SPR88 and SUM88 and their proportion in the pasture composition did not change as grazing progressed. Carpon desmodium increased in SPR88 when growth was initiated but did not change as grazing progressed in SUM88 after stands had stabilized.

Neither of the legumes was affected by stocking rate when analyzed as a component of the green herbage. Carpon desmodium, analyzed as a component of total legume, was lower at the light stocking rate than at the higher grazing intensities in SUM87. A taller canopy for the low

stocking rate evidently restricted some growth of the legume.

Stocking rate did not affect percentages of carpon desmodium or SLL in the green herbage in SPR88 or SUM88. Under continuous grazing, carpon desmodium can increase in pasture composition while stands of SLL will probably deteriorate under the stress of grazing.

Quantity and Nutritive Value of Available Herbage

The second objective of this study was to examine the effects of grazing intensity on the quantity and nutritive value of the herbage mixture. Pastures exhibited the effects of the different grazing intensities early in each season. There was a negative linear relationship between herbage mass and stocking rate. Herbage mass in the summer seasons did not decline until the latter part of the season at the light grazing intensity, while gradual declines were obtained over the season for moderate and heavy grazing intensities. Bahiagrass growth in SPR88 resulted in no declines in herbage mass over DOGR for the moderate and heavy intensities, while an increase was shown for the light grazing intensity.

Nutritive value of individual species was not affected by stocking rate, but there were changes in the measurements over the seasons. The nutritive value of SLL was relatively high throughout SUM87. Aeschynomene declined in L/S, IVDOM, and CP concentration of the leaves and stems. Top portions of the legume were grazed, leaving

lower leaves and stems that were lower in IVDOM and CP concentration. Phasey bean decreased in L/S early in the season, but nutritive value of the leaves remained constant.

In vitro digestible organic matter was low for leaves and stems of carpon desmodium in SUM88, but CP concentration was high in the leaves. Leaf to stem ratio and the nutritive value estimates of leaves and stems decreased early in the season, but stabilized later in the season.

In vitro digestible organic matter and CP concentration of total herbage declined over both summer seasons. In vitro digestible organic matter in SUM87 was positively correlated with percentages of bahiagrass and SLL, and negatively correlated with dead herbage in the pastures, while IVDOM in SUM88 was positively correlated with percentage of bahiagrass and negatively correlated with dead herbage. Low percentage of SLL in SUM88 and the low extent of IVDOM for carpon desmodium resulted in the legumes not having an influence on DOM in the pastures in SUM88. Crude protein concentration in SUM87 and SUM88 was positively correlated with SLL and carpon desmodium, respectively. Extent of IVDOM and CP concentration increased as grazing progressed in SPR88, when pasture growth was rapid.

Aeschynomene and phasey bean improved nutritive value of the bahiagrass pastures when they were in adequate supply. Carpon desmodium was low in IVDOM and failed to

affect digestibility of pastures, however, the legume increased CP concentration in the pastures.

Soil Seed Reserves

The third objective was to determine stocking rate effects on soil seed reserves. Reserves of aeschynomene seed in the soil were affected by stocking rate. Furthermore, there was a build-up of seed over the two summer seasons. Under light and moderate grazing intensities, aeschynomene can produce substantial reserves of seed which have the potential to provide natural reseeding when the sod is disturbed to reduce grass competition and moisture is adequate for seedling growth.

Seed production for carpon desmodium was extremely low following the first summer. However, soil seed reserves were substantial following SUM88, and were not affected by stocking rate. Carpon desmodium can tolerate heavy grazing through the summer and produce quantities of seed similar to those produced after being grazed under a light intensity.

Diet and Performance of Animals

The fourth objective was to evaluate the effects of grazing intensity and pasture responses on diet composition and animal performance. Grass was the major component of the diet over both summer seasons. The components of the diet were not affected by stocking rate, except for carpon

desmodium in SUM87 where the legume decreased in the diet as stocking rate increased and reduced the accessibility of the legume.

Selectivity ratios showed grass to be consumed in proportion to percentages of the component in the whole canopy. Carpon desmodium appeared to be avoided in SUM87, but a high percentage of the legume may have been inaccessible. The legume in SUM88 was consumed in proportion to percentage of the component in the whole canopy. Selectivity ratios for SLL were high in both seasons and indicate the high palatability of these legumes.

Average daily gain decreased linearly with increases in stocking rate. Average daily gain was higher over the first period (28 DOGR) for both summer seasons when available forage and forage quality of the legumes were highest. Animal performance was positively correlated with SLL percentage in SUM87, and with carpon desmodium in the pasture composition in SUM88.

There was a curvilinear increase in gain per hectare as stocking rate increased. However, there was a curvilinear decrease in BW as stocking rate increased in SUM88 when there was considerable flooding.

Average daily gain increased as stocking rate decreased, but higher gain per hectare was achieved with moderate to heavy stocking rates. Animal performance was enhanced by legumes. Aeschynomene and phasey bean contributed to animal performance by increasing both IVDOM

and CP concentration of pasture herbage. The benefit of carpon desmodium was through increasing CP concentration in the available herbage. Cattle selected aeschynomene and phasey bean over carpon desmodium, but even low percentage of carpon desmodium in the diet may overcome deficiencies in CP typical of bahiagrass pastures in mid-summer.

Implications of the Research

Results of the study indicate that establishment of carpon desmodium in bahiagrass pastures can be successful when planted in mixture with SLL. Short-lived legumes can establish early and provide a high-quality component to the diet. Stands of carpon desmodium will establish after the first year of grazing to provide a stable component to pastures. Deterioration of SLL stands under continuous grazing appears to be partially due to the high degree with which they are selectively grazed. Once established, carpon desmodium was indicated to be grazed in proportion to its percentage in the pasture botanical composition, which could allow the legume to persist when grazed continuously.

APPENDIX

Table A.1. Percentage of each component in the total herbage for each stocking rate (SR) in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	Bahia-grass	Carpon desmodium	Short-lived legumes†	Weed‡	Dead Herbage
	animals ha^{-1}			%		
SUM87	2.0	61.2	1.0	2.7	5.0	30.1
	3.5	58.7	1.5	2.5	5.3	32.1
	5.0	59.1	1.0	2.2	4.9	32.9
	SE§	3.6	0.8	0.4	1.2	4.3
SPR88	2.0	28.9	3.3	0.6	4.6	64.6
	3.5	30.7	3.5	0.6	4.5	60.7
	5.0	30.9	2.1	0.5	4.4	62.6
	SE	0.9	0.6	0.2	1.0	1.5
SUM88	3.0	37.2	2.6	0.6	3.1	56.5
	5.3	38.4	5.9	1.0	3.4	51.2
	7.5	45.0	0.5	1.9	3.0	49.7
	SE	0.6	4.1	0.4	0.5	4.2

† Aeschynomene and phasey bean.
‡ Bermudagrass and sedges.
§ Standard error of a treatment mean.

Table A.2. Effect of days of grazing (DOGR) on percentage of each component in the total herbage for the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	DOGR	Bahia-grass	Carpon desmodium	Short-lived legumes†	Weed‡	Dead Herbage
		%				
SUM87	1	76.8	0.4	3.6	5.7	13.5
	7	65.9	1.3	3.5	5.7	23.6
	14	66.0	1.2	2.7	5.3	24.8
	28	60.0	1.6	2.6	4.1	31.7
	42	53.6	1.3	2.0	5.1	38.0
	56	50.8	1.6	1.9	5.0	40.7
	71	44.3	0.8	0.8	4.5	49.6
	SE§	2.0	0.4	0.3	0.8	1.9
	Response¶	L***	L***,Q***	L***,Q**	L***	L***,Q**
SPR88	1	23.4	2.3	0.4	4.6	69.3
	28	30.7	4.9	0.5	4.1	59.7
	56	36.4	1.7	0.8	4.7	56.4
	SE	2.6	0.5	0.2	0.8	2.3
	Response	Q**	L***,Q**	NS	L*,Q*	L***,Q*
SUM88	1	54.8	3.8	0.9	4.5	36.0
	28	34.6	3.5	0.6	2.7	58.5
	71	31.1	3.1	0.6	2.3	62.9
	SE	2.5	0.9	0.2	0.5	2.1
	Response	L***,Q*	NS	NS	NS	L***,Q*

† Aeschynomene and phasey bean.
‡ Bermudagrass and sedges.
§ Standard error of a treatment mean.
¶ NS = not significant. Linear (L) or quadratic (Q) response with probability $P < 0.001$ (***), $P < 0.01$ (**), or $P < 0.05$ (*).

Table A.3. Percentage of each component in the green herbage for each stocking rate (SR) in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	Bahia-grass	Carpon desmodium	Short-lived legumes†	Weed‡
	animals ha^{-1}		%		
SUM87	2.0	87.3	1.5	3.9	7.3
	3.5	86.1	2.4	3.5	8.0
	5.0	87.9	1.4	3.0	7.7
	SE§	1.6	0.3	0.4	1.2
SPR88	2.0	76.2	9.2	1.5	13.1
	3.5	77.7	8.8	1.6	11.9
	5.0	81.2	5.8	1.1	11.9
	SE	3.7	1.9	0.3	3.1
SUM88	3.0	85.4	6.0	1.4	7.2
	5.3	78.6	11.8	2.2	7.4
	7.5	89.4	3.5	0.9	6.2
	SE	3.6	3.7	0.5	1.9

† Aeschynomene and phasey bean.
‡ Bermudagrass and sedges.
§ Standard error of a treatment mean.

Table A.4. Percentage of each component in the green herbage over days of grazing (DOGR) in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	DOGR	Bahia-grass	Carpon desmodium	Short-lived legumes†	Weed‡
		%			
SUM87	1	88.8	0.5	4.2	6.5
	7	86.3	1.7	4.5	7.5
	14	87.5	1.6	3.7	7.2
	28	87.9	2.3	3.9	5.9
	42	86.1	2.0	3.3	8.6
	56	85.6	2.7	3.1	8.6
	71	87.6	1.6	1.6	9.2
	SE§	2.3	0.4	0.6	1.7
SPR88	1	75.5	7.6	1.3	15.6
	28	76.4	12.2	1.3	10.1
	56	83.2	3.9	1.7	11.2
	SE	3.2	1.0	0.3	2.7
SUM88	1	85.4	5.8	1.7	7.1
	28	83.5	8.0	1.5	7.0
	71	84.5	7.6	1.6	6.3
	SE	3.0	0.4	2.4	1.7

† Aeschynomene and phasey bean.
‡ Bermudagrass and sedges.
§ Standard error of a treatment mean.

Table A.5. Percentages of carpon desmodium and short-lived legumes in the total legume component for each stocking rate (SR) in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	Carpon desmodium	Short-lived legumes†	SE‡
	animals ha^{-1}	%		
SUM87	2.0	27.4	72.6	0.04
	3.5	38.6	61.4	0.05
	5.0	36.7	63.3	0.04
SPR88	2.0	82.2	17.8	0.04
	3.5	80.2	19.8	0.04
	5.0	80.1	19.9	0.05
SUM88	3.0	79.2	20.8	0.04
	5.3	81.6	18.4	0.04
	7.5	83.6	16.4	0.03

† Aeschynomene and phasey bean.
‡ Standard error of a treatment mean.

Table A.6. Percentages of carpon desmodium and short-lived legumes in the total legume component over days of grazing (DOGR) in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	DOGR	Carpon desmodium	Short-lived legumes†	SE‡
		%	%	
SUM87	1	7.8	92.2	0.05
	7	26.8	73.2	0.04
	14	30.6	69.4	0.04
	28	35.7	64.3	0.04
	42	41.0	59.0	0.06
	56	49.1	50.9	0.05
	71	48.8	51.2	0.06
SPR88	1	85.4	14.6	0.03
	28	89.9	10.1	0.02
	56	67.2	32.8	0.04
SUM88	1	78.4	21.6	0.02
	28	83.1	16.9	0.04
	71	83.0	17.0	0.05

† Aeschynomene and phasey bean.
‡ Standard error of a treatment mean.

Table A.7. In vitro digestible organic matter (IVDOM) and crude protein (CP) concentration for total herbage at each stocking rate in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	IVDOM	CP
	animals ha^{-1}	g kg^{-1} OM	g kg^{-1} DM
SUM87	2.0	336	70
	3.5	333	70
	5.0	332	67
	SE†	6.5	1.6
SPR88	2.0	381	64
	3.5	396	67
	5.0	397	67
	SE	10.8	1.9
SUM88	3.0	371	62
	5.3	384	65
	7.5	389	65
	SE	4.7	1.0

† Standard error of a treatment mean.

Table A.8. Average daily gain (ADG) and gain per hectare for each stocking rate in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	ADG	Gain per hectare
	animals ha^{-1}	kg	
SUM87	2.0	0.70	99.9
	3.5	0.59	147.5
	5.0	0.46	164.5
	SE†	0.06	12.4
SPR88	2.0	0.62	69.8
	3.5	0.57	111.7
	5.0	0.50	140.9
	SE	0.08	15.3
SUM88	3.0	-0.14	-30.5
	5.3	-0.22	-85.3
	7.5	-0.35	-188.1
	SE	0.07	29.4

† Standard error of a treatment mean.

Table A.9. Leaf to stem ratio (L/S), in vitro digestible organic matter (IVDOM), and crude protein (CP) concentrations for aeschynomene and phasey bean at each stocking rate (SR) in the summer of 1988.

Legume	SR	L/S	IVDOM leaf	IVDOM stem	CP leaf	CP stem
	animals ha^{-1}		$g\ kg^{-1}$ OM		$g\ kg^{-1}$ DM	
Aeschynomene	2.0	0.64	760	418	249	77
	3.5	0.68	741	410	232	73
	5.0	0.66	751	405	221	73
	SE†	0.10	11.3	8.0	13.7	2.9
Phasey bean	2.0	0.97	751	574	232	87
	3.5	1.07	753	573	232	89
	5.0	1.15	757	570	225	85
	SE	0.10	6.9	6.5	9.1	2.9

† Standard error of a treatment mean.

Table A.10. Leaf to stem ratio (L/S), in vitro digestible organic matter (IVDOM), and crude protein (CP) concentration for carpon desmodium at each stocking rate (SR) in the summer of 1988.

SR	L/S	IVDOM leaf	IVDOM stem	CP leaf	CP stem
animals ha^{-1}		$g\ kg^{-1}$ OM		$g\ kg^{-1}$ DM	
3.0	0.59	456	354	174	59
5.3	0.53	479	337	174	57
7.5	0.56	469	335	180	58
SE†	0.10	16.6	12.6	9.1	3.2

† Standard error of a treatment mean.

Table A.11. In vitro digestible organic matter (IVDOM) and crude protein (CP) concentration for bahiagrass at each stocking rate in the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	IVDOM	CP
	animals ha^{-1}	g kg^{-1} OM	g kg^{-1} DM
SPR88	2.0	523	101
	3.5	522	93
	5.0	527	103
	SE†	12.4	3.8
SUM88	3.0	502	67
	5.3	509	68
	7.5	524	69
	SE	18.5	3.6

† Standard error of a treatment mean.

Table A.12. In vitro digestible organic matter (IVDOM) and crude protein (CP) concentration for total herbage at each stocking rate in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	IVDOM	CP
	animals ha^{-1}	g kg^{-1} OM	g kg^{-1} DM
SUM87	2.0	336	70
	3.5	333	70
	5.0	332	67
	SE†	6.5	1.6
SPR88	2.0	381	64
	3.5	396	67
	5.0	397	67
	SE	10.8	1.9
SUM88	3.0	371	62
	5.3	384	65
	7.5	389	65
	SE	4.7	1.0

† Standard error of a treatment mean.

Table A.13. Average daily gain (ADG) and gain per hectare for each stocking rate in the summer of 1987 (SUM87), and the spring (SPR88) and summer (SUM88) of 1988.

Season	SR	ADG	Gain per hectare
	animals ha^{-1}	kg	
SUM87	2.0	0.70	99.9
	3.5	0.59	147.5
	5.0	0.46	164.5
	SE†	0.06	12.4
SPR88	2.0	0.62	69.8
	3.5	0.57	111.7
	5.0	0.50	140.9
	SE	0.08	15.3
SUM88	3.0	-0.14	-30.5
	5.3	-0.22	-85.3
	7.5	-0.35	-188.1
	SE	0.07	29.4

† Standard error of a treatment mean.

Table A.14. Diet composition and selection ratio for each stocking rate in the summers of 1987 (SUM87) and 1988 (SUM88).

Season	SR	Component	Diet Composition		Selection ratio	
	animals ha^{-1}		—— % ——			
SUM87	2.0	Grass	82.0	(2.4)†	-1	(0.1)†
		CD	1.7	(0.5)	0	(1.2)
		SLL	16.3	(2.3)	+7	(0.7)
	3.5	Grass	84.5	(1.0)	0	(0.1)
		CD	0.7	(0.2)	-6	(1.4)
		SLL	14.8	(1.0)	+7	(1.0)
	5.0	Grass	87.4	(1.6)	0	(0.1)
		CD	0.2	(0.1)	-8	(1.4)
		SLL	12.4	(1.6)	+7	(0.7)
SUM88	3.0	Grass	89.1	(1.2)	0	(0.1)
		CD	6.2	(0.7)	0	(0.6)
		SLL	4.6	(1.0)	+6	(1.1)
	5.3	Grass	87.6	(1.8)	0	(0.3)
		CD	7.2	(1.4)	-1	(1.4)
		SLL	5.1	(0.9)	+4	(1.7)
	7.5	Grass	91.6	(0.6)	0	(0.1)
		CD	5.4	(0.6)	+2	(1.7)
		SLL	2.9	(0.6)	+5	(1.3)

† Standard error of a treatment mean.

LITERATURE CITED

Adjei, M.B., and F.K. Fianu. 1985. The effect of cutting interval on the yield and nutritive value of some tropical legumes on the coastal grassland of Ghana. Trop. Grassl. 19:164-170.

Adjei, M.B., P. Mislevy, and C.Y. Ward. 1980. Response of tropical grasses to stocking rate. Agron. J. 72:863-868.

Akin, D.E., and D. Burdick. 1975. Percentage of tissue types in tropical and temperate grass leaf blades and degradation of tissues by rumen microorganisms. Crop Sci. 15:661-668.

Albrecht, S.L., J.M. Bennett, and K.H. Quesenberry. 1981. Growth and nitrogen fixation of Aeschynomene under water stressed conditions. Plant Soil 60:309-315.

Allen, L.H., Jr. 1977. Soil water and root development. Soil Crop Sci. Soc. Fla. Proc. 36:4-8.

Arnold, G.W. 1980. Grazing behavior. p. 79-104. In F.H.W. Morley (ed.) Grazing animals. Elsevier Scientific Publishing Company, Amsterdam, Holland.

Baumgartner, L.L., and A.C. Martin. 1939. Plant histology as an aid in squirrel food-habit studies. J. Wildl. Manage. 3:266-268.

Beaty, E.R., R.H. Brown, and J.B. Morris. 1970. Response of Pensacola bahiagrass to intense grazing. p. 538-542. In M.J.T. Norman (ed.) Proc. 11th Int. Grassl. Congr. Surfers Paradise, Australia. 13-23 Apr. 1970. Univ. of Queensland Press, St. Lucia, Queensland, Australia.

Beaty, E.R., R.A. McCreery, and J.D. Powell. 1960. Response of Pensacola bahiagrass to nitrogen fertilization. Agron. J. 52:453-455.

Beaty, E.R., J.D. Powell, R.H. Brown, and W.J. Ethredge. 1963. Effect of nitrogen and clipping frequency on yield of Pensacola bahiagrass. Agron. J. 55:3-4.

Beaty, E.R., R.L. Stanley, and J. Powell. 1968. Effect of height of cut on yield of Pensacola bahiagrass. Agron. J. 60:356-358.

Bertrand, J.E., and L.S. Dunavin. 1985. Grazing evaluation of two hybrid bermudagrasses, Callie bermudagrass and Pensacola bahiagrass in north Florida. p. 67-70. In Fla. Beef Cattle Res. Rep. Univ. of Fla., Gainesville.

Bishop, H.G., D.H. Ludke and M.T. Rutherford. 1985. Glenn jointvetch: A new pasture legume for Queensland coastal areas. Queensland Agric. J. 111:241-245.

Blue, W.G. 1970. Fertilizer nitrogen uptake by Pensacola bahiagrass (Paspalum notatum) from Leon fine sand, a spodosol. p. 389-392. In M.J.T. Norman (ed.) Proc. 11th Int. Grassl. Congr. Surfers Paradise, Australia. 13-23 Apr. 1970. Univ. of Queensland Press, St. Lucia, Queensland, Australia.

Bogdan, A.V. 1977. Tropical pasture and fodder plants. Longman, Inc., New York, NY.

Brolmann, J.B., and A.E. Kretschmer, Jr. 1973. Agronomical and morphological characteristics of phasey bean. Soil Crop Sci. Soc. Fla. Proc. 32:50-52.

Brown, W.F., and J.E. Moore. 1987. Analysis of forage research samples utilizing a combination of wet chemistry and near infrared reflectance spectroscopy. J. Anim. Sci. 64:271-282.

Burton, G.W. 1946. Bahiagrass types. J. Am. Soc. of Agron. 38:273-281.

Cameron, D.G. 1985. Tropical and subtropical pasture legumes 8. Phasey bean (Macroptilium lathyroides): The predecessor of Siratro. Queensland Agric. J. 111:211-214.

Chacon, E., and T.H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behavior of cattle. Aust. J. Agric. Res. 27:709-727.

Chambliss, C.G., and D.W. Jones. 1981. Bahiagrass. Fla. Coop. Ext. Serv. Circ. 321B.

Chapman, J.D., W.H. Marchant, P.R. Utley, R.E. Hellwig, and W.G. Monson. 1972. Performance of steers on Pensacola bahiagrass, Coastal bermudagrass and Coastcross-1 bermudagrass pastures and pellets. J. Anim. Sci. 34:373-378.

Coates, D.B., P. Schachenmann, and R.J. Jones. 1987. Reliability of extrusa samples collected from steers fistulated at the oesophagus to estimate the diet of resident animals in grazing experiments. Aust. J. Exp. Agric. 27:739-745.

Coleman, S.W., F.E. Barton, II, and R.D. Meyer. 1985. The use of near-infrared reflectance spectroscopy to predict species composition of forage mixtures. Crop Sci. 25:834-837.

Conniffe, D., D. Brown, and M.J. Walshe. 1970. An example of a method of statistical analysis of a grazing experiment. J. Agric. Sci. (Camb.) 79:165-167.

Connolly J. 1976. Some comments on the shape of the gain-stocking rate curve. J. Agric. Sci. (Camb.) 86:103-109.

Cowlishaw, S.J. 1962. The carrying capacity of pastures. J. Br. Grassl. Soc. 24:207-214.

Dearden, B.L., R.E. Pegau, and R.M. Hansen. 1975. Precision of microhistological estimate of ruminant food habits. J. Wildl. Manage. 39:402-407.

Duble, R.L., J.A. Lancaster, and E.C. Holt. 1971. Forage characteristics limiting animal performance on warm-season perennial grasses. Agron. J. 63:795-798.

Dzowela, B.H., G.O. Mott, and W.R. Ocumpaugh. 1986. Summer grazing management of a white clover-bahiagrass pasture: Legume survival. Expl. Agric. 22:363-371.

Eng, P.K., P.C. Kerridge, and L. t'Mannetje. 1978. Effects of phosphorous and stocking rate on pasture and animal production from a guinea grass-legume pasture in Johore, Malaysia: 1. Dry matter yields, botanical and chemical composition. Trop. Grassl. 12:188-197.

Finlayson, E.H. 1941. Pensacola--A new fine-leaved bahiagrass. Southern Seedsman 4:9.

Forbes, T.D.A., E.M. Smith, R.B. Razor, C.T. Dougherty, V.G. Allen, and L.L. Erlinger. 1985. The plant-animal interface. p. 95-116. In V.H. Watson and C.M. Wells (eds.) Simulation of Forage & Beef Production in the Southern Region. Southern Cooperative Series Bull. 308.

Fracker, S.B., and J.A. Brischle. 1944. Measuring the local distribution of Ribes. Ecology 25:283-303.

Freund, R.J., R.C. Little, and P.C. Spector. 1986. SAS system for linear models: A guide to the ANOVA and GLM procedures. 1986 ed. SAS Institute, Inc. Cary, NC.

Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digestor for plant and soil analysis. Soil Sci. Soc. Am. Proc. 39:803-806.

Gildersleeve, R.R. 1982. Agronomic evaluation of Aeschy-nomene species under grazing. M.S. Thesis. Univ. of Fla., Gainesville.

Gould, F.W. 1975. The grasses of Texas. 1st ed. Texas A&M Univ. Press. College Station.

Grime, J.P. 1973. Competitive exclusion in herbaceous vegetation. Nature 242:344-347.

Grime, J.P. 1974. Vegetation classification by reference to strategies. Nature 250:26-31.

Guerrero, J.N., B.E. Conrad, E.C. Holt, and H. Wu. 1984. Prediction of animal performance on bermudagrass pasture from available forage. Agron. J. 76:577-580.

Hambleton, L.G. 1977. Semiautomated method of simultaneous determination of phosphorus, calcium and crude protein in animal feeds. J.A.O.A.C. 60:845-852.

Hammond, A.C. 1987. Chemical, anatomical and other antiquality factors limiting forage utilization. p. 59-69. In J.E. Moore, K.H. Quesenberry, and M.W. Michaud (eds.) Forage-Livestock Research Needs for the Caribbean Basin. 9-12 Feb., 1987. Caribbean Basin Advisory Group, Gainesville, FL.

Harlan, J.R. 1958. Generalized curves for gain per head and gain per acre in rates of grazing studies. J. Range Manage. 11:140-147.

Heady, H.F., and D.T. Torrell. 1959. Forage preferences exhibited by sheep with esophageal fistulas. J. Range Manage. 12:28-34.

Heaney, D.P. 1970. Voluntary intake as a component of an index to forage quality. In R.F. Barnes, D.C. Clanton, C.H. Gordon, T.J. Klopfenstein, and D.R. Waldo (eds.) Proc. Nat. Conf. Forage Quality Eval. and Util. 3-4 Sep., 1969. Nebraska Center for Continuing Educ., Lincoln, NE.

Henderson, M.S., and D.L. Robinson. 1982. Environmental influences on yield and in vitro true digestibility of warm-season perennial grasses and the relationships to fiber components. Agron. J. 74:943-946.

Hodges, E.M., A.E. Kretschmer, Jr., P. Mislevy, R.D. Roush, O.C. Ruelke, and G.H. Snyder. 1982. Production and utilization of the tropical legume Aeschynomene. Fla. Agric. Exp. Stn. Circ. S-290. Univ. of Fla., Gainesville.

Hodges, E.M., and J.E. McCaleb. 1972. Aeschynomene in pasture programs. p. 19-23. In Beef cattle and forage field day program. Ona ARC Res. Rep. RC-1972-2, Univ. of Fla., Ona.

Hodges, E.M., F.M. Peacock, H.L. Chapman, Jr., and R.E.L. Greene. 1974. Forage and supplement systems for beef cows in south-central Florida. Soil Crop Sci. Soc. Fla. Proc. 33:56-59.

Hodges, E.M., F.M. Peacock, H.L. Chapman, Jr., and F.G. Martin. 1976. Grazing trials with tropical grasses and legumes in peninsular Florida. Soil Crop Sci. Soc. Fla. Proc. 35:84-86.

Holechek, J.L., M. Vavra, and R.D. Pieper. 1982. Botanical composition determination of range herbivore diets: A review. J. Range. Manage. 35:309-315.

Jamieson, W.S., and J. Hodgson. 1979a. The effect of daily herbage allowance and sward characteristics upon the ingestive behavior and herbage intake of calves under strip-grazing management. Grass Forage Sci. 34:261-271.

Jamieson, W.S., and J. Hodgson. 1979b. The effects of variation in sward characteristics upon the ingestive behavior and herbage intake of calves and lambs under a continuous stocking management. Grass Forage Sci. 34:273-282.

Jones, R.J. 1981. Interpreting fixed stocking rate experiments. p. 419-429. In J.L. Wheeler, and R.D. Mochrie (eds.) Forage evaluation: Concepts and techniques. Proc. of workshop held 27-31 Oct. 1980 at Armidale, NSW, Australia. Am. Forage and Grassl. Council, Lexington, KY.

Jones, R.J., and R.L. Sandland. 1974. The relation between animal gain and stocking rate. J. Agric. Sci. (Camb.) 83:335-342.

Kalmbacher, R.S., and F.G. Martin. 1983. Light penetrating a bahiagrass canopy and its influence on establishing jointvetch. Agron. J. 75:465-468.

Kothmann, M.M., and R.T. Hinnant. 1987. Nitrogen fertilization of bahiagrass and native vegetation. Tex. Agr. Exp. Stn. Misc. Publ. 1629, College Station.

Kretschmer, A.E., Jr. 1970. Production of annual and perennial tropical legumes in mixtures with pangolagrass and other grasses in Florida. p. 149-153. In M.J.T. Norman (ed.) Proc. 11th Int. Grassl. Congr. Surfers Paradise, Australia. 13-23 Apr. 1970. Univ. of Queensland Press, St. Lucia, Queensland, Australia.

Kretschmer, A.E., Jr., J.B. Brolmann, G.H. Snyder, and S.W. Coleman. 1976. 'Florida' carpon desmodium, a perennial tropical legume for use in south Florida. Soil Crop Sci. Soc. Fla. Proc. 35:25-31.

Kretschmer, A.E., Jr., J.B. Brolmann, G.H. Snyder, and S.W. Coleman. 1979. 'Florida' carpon desmodium, a perennial tropical forage legume for use in south Florida. Fla. Agric. Exp. Stn. Circ. S-260. Univ. of Fla., Gainesville.

Kretschmer, A.E., Jr., J.B. Brolmann, G.H. Snyder, and S.W. Coleman. 1982. Registration of 'Florida' carpon desmodium (Reg. No. 24). Crop Sci. 22:158-159.

Kretschmer, A.E., Jr., J.B. Brolmann, G.H. Snyder, and G.J. Gascho. 1973. Production of six tropical legumes each in combination with three tropical grasses in Florida. Agron. J. 65:890-892.

Kretschmer, A.E., Jr., and R.C. Bullock. 1980. Aeschynomene spp.: Distribution and potential use. Soil Crop Sci. Soc. Fla. Proc. 39:145-152.

Kretschmer, A.E., Jr., and G.H. Snyder. 1982. Comparison of mixtures of seven tropical legumes and six tropical grasses in south Florida. Soil Crop Sci. Soc. Fla. Proc. 41:67-72.

Laidlaw, A.S. 1983. Grazing by sheep and the distribution of species through the canopy of a red clover-perennial ryegrass sward. Grass Forage Sci. 38:317-321.

Laredo, M.A., and D.J. Minson. 1973. The voluntary intake, digestibility, and retention time by sheep of leaf and stem fractions of five grasses. Aust. J. Agric. Res. 24:875-888.

Laycock, W.A., H. Buchanan, and W.C. Krueger. 1972. Three methods for determining diet, untilization and trampling damage on sheep ranges. J. Range. Manage. 25:352-356.

Ludlow, M.M., T.H. Stobbs, R. Davis, and D.A. Charles-Edwards. 1982. Effect of sward structure of two tropical grasses with contrasting canopies on light distribution, net photosynthesis and size of bite harvested by cattle. Aust. J. Agric. Res. 33:187-201.

Martin, G.C. 1978. The animal-plant complex in forage palatability phenomena. J. Anim. Sci. 46:1471-1477.

McCartor, M.M., and F.M. Rouquette, Jr. 1977. Grazing pressures and animal performance from pearl millet. Agron. J. 69:983-987.

Milford, R. 1967. Nutritive values and chemical composition of seven tropical legumes and lucerne grown in subtropical south-eastern Queensland. Aust. J. Exp. Agric. Anim. Husb. 7:540-545.

Milne, J.A., J. Hodgson, R. Thompson, W.G. Souter, and G.T. Barthram. 1982. The diet ingested by sheep grazing swards differing in white clover and perennial ryegrass content. Grass Forage Sci. 37:209-218.

Minson, D.J. 1980a. Relationships of conventional and preferred fractions to determined energy values. p. 72-78. In W.J. Pigden, C.C. Balch, and M. Graham (eds.) Standardization of analytical methodology for feeds. Int. Development Res. Center, Ottowa, Canada.

Minson, D.J. 1980b. Nutritional differences between tropical and temperature pastures. p. 143-157. In F.H.W. Morley (ed.) Grazing animals. Elsevier Scientific Publishing Co., Amsterdam, Holland.

Minson, D.J., and R. Milford. 1967. The voluntary intake and digestibility of diets containing different proportions of legume and mature pangola grass (Digitaria decumbens). Aust. J. Exp. Agric. Anim. Husb. 7:546-550.

Mislevy, P., and P.H. Everett. 1981. Subtropical grass species response to different irrigation and harvest regimes. Agron. J. 73:601-604.

Mislevy, P., and E.M. Hodges. 1976. Grazing management on digitgrass and bahiagrass. Soil Crop Sci. Soc. Fla. Proc. 35:76-79.

Mislevy, P., R.S. Kalmbacher, and F.G. Martin. 1981. Cutting management of the tropical legume American jointvetch. Agron. J. 73:771-775.

Mislevy, P., and F.G. Martin. 1985. Changes in production and quality with plant elongation and maturity of American jointvetch. p. 1051-1052. In I. Nikki (ed.) Proc. 15th Int. Grassl. Congr., Kyoto, Japan. 24-30 Aug., 1985. Nishi-nasuno, Tochigiken, Japan.

Moore, J.E. 1980. Forage crops. p. 61-94. In C.S. Hoveland (ed.) Crop quality, storage, and utilization. Am. Soc. Agron. and Crop Sci. Soc. Am., Madison, WI.

Moore, J.E. 1981. Principles of forage quality evaluation. p. 66-87. In King Visiting Scholar Lectures. Ark. Agric. Exp. Stn. Special Rep. 93.

Moore, J.E., J.C. Burns, A.C. Linnerud, and R.J. Monroe. 1980. Relationships between the properties of southern forages and animal response. p. 19-36. Proc. Southern Pasture Forage Crop Imp. Conf., Nashville, TN.

Moore, J.E., G.L. Ellis, C.E. Rios, and M. Koger. 1969. Estimates of the voluntary intake and nutrient digestibility of bahiagrass pasture by grazing steers. Soil Crop Sci. Soc. Fla. Proc. 29:168-175.

Moore, J.E., and G.O. Mott. 1974. Recovery of residual organic matter from *in vitro* digestion of forages. J. Dairy Sci. 57:1258-1259.

Moore, J.E., O.C. Ruelke, C.E. Rios, and D.E. Franke. 1970. Nutritive evaluation of Pensacola bahiagrass hays. Soil Crop Sci. Soc. Fla. Proc. 30:211-221.

Mott, G.O. 1959. Symposium on forage evaluation. IV. Animal variation and measurement of forage quality. Agron. J. 51:223-225.

Mott, G.O. 1960. Grazing pressure and the measurement of pasture production. p. 606-611. In C.L. Sidmore (ed.) Proc. 8th Int. Grassl. Congr., Reading, England. 11-21 July 1960. Alder Press, Oxford, England.

Mott, G.O. 1980. Measuring forage quantity and quality in grazing trials. p. 3-9. Proc. 37th Southern Pasture and Forage Crop Imp. Conf., Nashville, TN.

Mott, G.O., and J.E. Moore. 1970. Forage evaluation techniques in perspective. p. L1-L10. In R.F. Barnes, D.C. Clanton, C.H. Gordon, T.J. Klopfenstein, and D.R. Waldo (eds.) Proc. Nat. Conf. Forage Quality Eval. and Util., Nebraska Center for Continuing Educ., Lincoln, NE.

Muldoon, D.K. 1985. Summer forages under irrigation 4. The growth and mineral composition of forage legumes. Aust. J. Expl. Agric. 25:417-423.

Othman, W.M.W., and C.J. Asher. 1987. The effects of defoliation on carbon assimilation, nitrogen fixation and regrowth of phasey bean (Macroptilium lathyroides (L.) Urb. cv. Murray). J. Aust. Inst. Agric. Sci. 53:36.

Partridge, I.J. 1979. Improvement of Nadi blue grass (Dichanthium caricosum) pastures on hill land in Fiji with superphosphate and siratro: Effects of stocking rate on beef production and botanical composition. Trop. Grassl. 13:157-164.

Petersen, R.G., H.L. Lucas, and G.O. Mott. 1965. Relationship between rate of stocking and per animal and per acre performance on pasture. Agron. J. 57:27-30.

Pitman, W.D. 1983. Initial comparisons of tropical legume-bahiagrass pastures and nitrogen-fertilized bahiagrass pastures in peninsular Florida. Soil Crop Sci. Soc. Fla. Proc. 42:72-75.

Pitman, W.D., C.G. Chambliss, and A.E. Kretschmer, Jr. 1988. Persistence of tropical legumes on peninsular Florida flatwoods (Spodosols) at two stocking rates. Trop. Grassl. 22:27-33.

Pitman, W.D., and R.S. Kalmbacher. 1983. Effect of length of fall grazing period on seed production of Aeshynomene americana. p. 1-2. In Fla. Acad. Sci. Abstr. Univ. of Fla., Gainesville.

Pitman, W.D., and A.E. Kretschmer, Jr. 1984. Persistence of selected tropical pasture legumes in peninsular Florida. Agron. J. 76:993-996.

Pitman, W.D., A.E. Kretschmer, Jr., and C.G. Chambliss. 1986. Phasey bean, a summer legume with forage potential for Florida flatwoods. Fla. Agric. Exp. Stn. Circ. S-330. Univ. of Fla., Gainesville.

Prates, E.R., H.L. Chapman, Jr., E.M. Hodges, and J.E. Moore. 1975. Animal performance by steers grazing Pensacola bahiagrass pasture in relation to forage production, forage consumption, and estimated intake. Soil Crop Sci. Soc. Fla. Proc. 34:152-156.

Quesenberry, K.H., and W.R. Ocumpaugh. 1981. Forage potential of Aeschynomene species in North Central Florida. Soil Crop Sci. Soc. Fla. Proc. 40:159-162.

Riewe, M.E. 1961. Use of the relationship of stocking rate to gain of cattle in an experimental design for grazing trials. Agron. J. 53:309-313.

Roberts, C.R. 1980. Effect of stocking rate on tropical pastures. Trop. Grassl. 14:225-231.

Rusland, G.A., L.E. Sollenberger, K.A. Albrecht, C.S. Jones, Jr., and L.V. Crowder. 1988. Animal performance on limpograss-aeschynomene and nitrogen-fertilized limpograss pastures. Agron. J. 80:957-962.

Sampaio, E.V.S.B., and E.R. Beaty. 1976. Morphology and growth of bahiagrass a three rates of nitrogen. Agron. J. 68:379-381.

Sampaio, E.V.S.B., E.R. Beaty, and D.A. Ashley. 1976. Bahiagrass regrowth and physiological aging. J. Range Manage. 29:316-319.

Schroder, V.N. 1966. Photosynthesis and respiration of four pasture grasses as affected by moisture conditions and salinity. p. 181-184. In A.G.G. Hill (ed.) Proc. 10th. Int. Grassl. Congr., Helsinki, Finland. 7-16 July 1966. Valtioneuvoston Kirjapaino, Helsinki, Finland.

Scott, J.M. 1920. Bahiagrass. J. Am. Soc. of Agron. 12:112-114.

Shenk, J.S., I. Landa, M.R. Hoover, and M.O. Westerhaus. 1981. Description and evaluation of a near infrared reflectance spectrocomputer for forage and grain analysis. Crop Sci. 21:355-358.

Sollenberger, L.E., J.E. Moore, K.H. Quesenberry, and P.T. Beede. 1987a. Relationships between canopy botanical composition and diet selection in aeschynomene-limpograss pastures. Agron. J. 79:1049-1054.

Sollenberger, L.E., W.R. Ocumpaugh, V.P.B. Euclides, J.E. Moore, K.H. Quesenberry, and C.S. Jones, Jr. 1988. Animal performance on continuously stocked 'Pensacola' bahiagrass and 'Floralta' limpograss pastures. J. Prod. Agric. 1:216-220.

Sollenberger, L.E., and K.H. Quesenberry. 1986. Seed production responses of Aeschynomene americana L. to grazing management. Soil Crop Sci. Soc. Fla. Proc. 45:157-161.

Sollenberger, L.E., K.H. Quesenberry, and J.E. Moore. 1987b. Effects of grazing management on establishment and productivity of aeschynomene overseeded in limpograss pastures. Agron. J. 79:78-82.

Sollenberger, L.E., K.H. Quesenberry, and J.E. Moore. 1987c. Forage quality responses of an aeschynomene-limpograss association to grazing management. Agron. J. 79:83-89.

Sparks, D.R., and J.C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range. Manage. 21:264-265.

Stanley, R.L., E.R. Beaty, and J.D. Powell. 1967. Effect of clipping height on forage distribution and regrowth of Pensacola bahiagrass. Agron. J. 59:185-186.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach. McGraw-Hill, New York, NY.

Stobbs, T.H. 1970. The use of liveweight-gain trials for pasture evaluation in the tropics: 6. A fixed stocking rate design. J. Br. Grassl. Soc. 25:73-77.

Stobbs, T.H. 1973a. The effect of plant structure on the intake of tropical pastures I. Variation in the bite size of grazing cattle. Aust. J. Agric. Res. 24:809-819.

Stobbs, T.H. 1973b. The effect of plant structure on the intake of tropical pastures II. Differences in sward structure, nutritive value, and bite size of animals grazing Setaria anceps and Chloris gayana at various stages of growth. Aust. J. Agric. Res. 24:821-829.

Tang, P.L., and O.C. Ruelke. 1977. Effects of management treatments on the reestablishment and persistence of Aeschynomene americana L. Soil Crop Sci. Soc. Fla. Proc. 36:149-152.

Taylor, C.A., M.M. Kothmann, L.B. Merrill, and Doak Elledge. 1980. Diet selection of cattle under high-intensity low-frequency, short duration, and Merrill grazing systems. J. Range Manage. 33:428-434.

Thompson, S. 1988. Range expansion by alien weeds in the coastal farmlands of Guyana. J. Biogeo. 15:109-118.

Utley, P.R., H.D. Chapman, W.G. Monson, W.H. Marchant, and W.C. McCormick. 1974. Coastcross-1 bermudagrass, Coastal bermudagrass and Pensacola bahiagrass as summer pasture for steers. J. Anim. Sci. 38:490-495.

Vavra, M., and J.L. Holechek. 1980. Factors influencing microhistological analysis of herbivore diets. J. Range Manage. 3:371-373.

Vavra, M., R.W. Rice, and R.M. Hannsen. 1978. A comparison of esophageal fistula and fecal material to determine steer diets. J. Range. Manage. 31:11-13.

Watson, V.H., and B.L. Burson. 1985. Bahiagrass, carpetgrass, and dallisgrass. 1985. p. 255-262. _In_ M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.) Forages: The science of grassland agriculture. Iowa State Univ. Press, Ames, IA.

Whiteman, P.C. 1980. Tropical Pasture Science. Oxford Univ. Press. Oxford, England.

Whiteman, P.C., M. Seitlheko, M.E. Siregar, A.K. Chudasama, and R.R. Javier. 1984. Short-term flooding tolerance of seventeen commercial tropical pasture legumes. Trop. Grassl. 18:91-96.

Wilkinson, S.R., W.E. Adams, and W.A. Jackson. 1970. Chemical composition and _in vitro_ digestibility in vertical layers of Coastal bermudagrass (_Cynodon dactylon_ L.). Agron. J. 62:39-43.

BIOGRAPHICAL SKETCH

Glen Eris Aiken was born in Brownwood, Texas, on June 20, 1952. Although not reared on a farm, he developed an interest in agriculture early in life when he was exposed to the meat-packing industry, and when he worked on his grandfather's beef cattle farm in north-central Texas. Glen graduated from Robert E. Lee High School in Houston, Texas, in 1971. He worked his way through college and received a degree in dairy science from Texas A&M University in 1979.

Following a four-year period of working in Louisiana oil fields, Glen went back to Texas A&M University to work in the area of pasture relations to horse management under the direction of Dr. G.D. Potter. Glen received his M.S. in animal science from Texas A&M in December 1986.

Glen enrolled at the University of Florida in August 1986, and is currently a candidate for the Doctor of Philosophy degree. He is married to Mary Austin Aiken, and they have two daughters, Helen and Martha.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W.D. Pitman

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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